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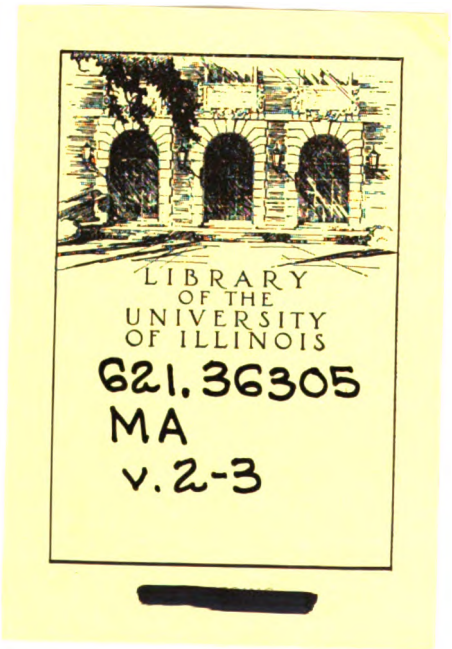
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No. 16

THE MARCONI REVIEW

January, 1930

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THE MARCONI REVIEW

No. 16. *January, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

A PORTABLE PRECISION FREQUENCY METER

The continued increase in the number of short wave radio stations has made it imperative that a frequency meter, capable of fine discrimination should be produced.

During the last few years, great efforts have been made by experimentalists to produce apparatus, transmitters in particular, which can be set to work at a certain frequency and relied upon to remain at that frequency with a very small percentage variation over long periods of time. Some engineers have applied themselves to the development of the piezo-electric oscillator, others to tuning forks and frequency doublers, and still others to the perfection of the condenser-inductance circuit. It is not the present purpose to discuss here the merits of the various systems but rather to consider what has been done to meet the resultant demand for apparatus capable of measuring the constancy of frequency of stations which use any of the well known systems of master oscillator, frequency multipliers, amplifiers, and power output apparatus.

There exist various Laboratory Standards for the measurement of frequency (such as the Alternator method of measurement of frequency, described in THE MARCONI REVIEW, *of April, 1929), which on account of their precision and structure, cannot be moved from place to place, or effectively handled except by experts. There also exist frequency meters of such great discrimination that they can only be regarded as second to fundamental standards, and which in consequence suffer some of the disadvantages of the fundamental standard.*

THE Marconi Company have realised the urgent need of a portable frequency meter of high accuracy, small temperature co-efficient, great mechanical rigidity, and good shielding, and have investigated the problem with a view to producing such an instrument.

The instrument which has been designed and made is shewn in Fig. 1, and the scheme of connections is shown in Fig. 2.

Referring to Figs. 1 and 2 it will be seen that the apparatus consists of a main condenser-inductance circuit, which can be coupled to a transmitting circuit by means of the aperiodic coupling coil and the two small feeder condensers. Coupled inductivity to the main condenser inductance circuit is a second aperiodic circuit which is connected to the detector valve. The schedule of items accompanying Fig. 2 is sufficiently explanatory, and the only unusual items are the small air condenser G.G., and the tapper key and switch H. The functions of these parts will be dealt with later. It was decided at the commencement of work on this subject that the normal range of the complete instrument should be from 30,000,000 cycles to

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3,000,000 cycles, *i.e.*, 10 to 100 metres but it was found later that this could be extended ; that the instrument should be fitted with a finely engraved scale of 100 useful divisions with a vernier pointer and that at the highest frequency one vernier division should represent a change of frequency of the order of 5,000 cycles.

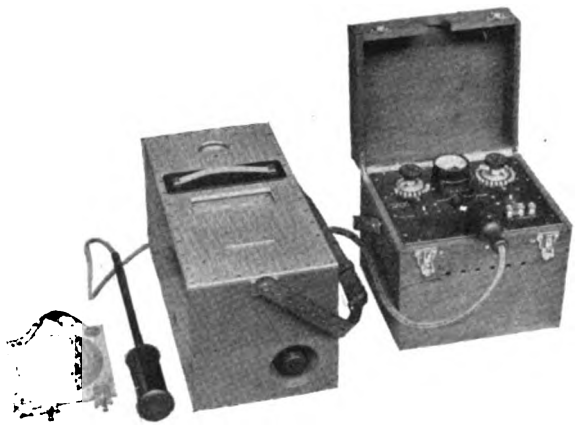

FIG. 1.

The general requirements of the instrument have been enumerated in the foregoing paragraphs, and the consideration of these points considerably influenced the design of the instrument.

The problem of solid insulators demanded serious attention. Although solid insulators of what might be termed second order have been used in parts of the instrument, these have not been employed at any point where their use would affect the stability or accuracy of the final apparatus. Wherever any doubt has arisen the material Mycalex has been employed. The reason for the use of Mycalex is that although ebonite is a good high frequency insulator it is well known that it has both fluid and acid qualities. Under the influence of quite ordinary temperatures, and very small strains, Ebonite will measurably change its shape, and also when exposed to the combined action of sunlight and damp the material will exude acid. The result of this is that in the first case an instrument, such as a condenser or inductance using Ebonite as an insulator can never be regarded as stable, and in the second case the surface leakage of the Ebonite will vary from time to time, and in consequence the power factor of the circuit will change, seriously affecting the accuracy of the instrument. Bakelite is not such a good high frequency insulator, it is chemically inert, but it has a large temperature coefficient. Glasses of various kinds and porcelain are excellent high frequency insulators and of low temperature coefficient, but the difficulty of working these materials rather precludes their use for an instrument of this type, and their brittleness is against hard usage. Mycalex is a good high frequency insulator, has a low temperature coefficient and can be worked with a fair amount of ease and exactitude.

It will be as well to describe in some detail the more important parts of the instrument. In the base of a cast aluminium case 18½ ins. long by 9 ins. high by 9 ins. wide, fitted with a sheet aluminium cover is securely fixed on six cast pillars a sheet of Mycalex 15 ins. long by 6 ins. wide by ⅜ in. thick, and upon this base is

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built the essential portions of the instrument. A reference to Fig. 2 and noting those items, excluding J contained within the dotted rectangle R, will indicate the permament fixed details of the system. The condenser E is of the variable series air dielectric type. It consists of two banks of fixed vanes of brass, mounted opposite to each other on solid brass supports which are secured to the Mycalex base, and one bank of double ended brass vanes which interleave with the two fixed banks mounted on a central spindle, whose lower end is fitted with a worm which engages with a worm giving a ratio of 1/100. Beneath the worm wheel, the central spindle is brought

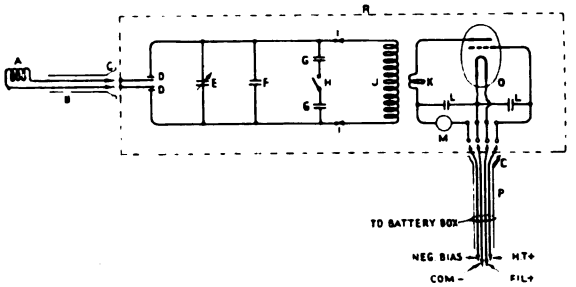

FIG. 2.

A. *Search Coil.*
B. *Twin core Armoured Cable H.F. Feeder.*
C.C. *Screwed glands covering plug connections.*
D.D. *Small Feeder Condensers.*
E. *Variable Air Condenser.*
F. *Fixed Air Condenser.*
G.G. *Small Air Condensers for Balancing.*
H. *Tapper Key and switch.*
I.I. *Sockets.*
J. *Inductance with plugs for connection to I.I.*
K. *Aperiodic Coil for coupling between tuned circuit and Detector Valve.*
L.L. *Mica Condensers shunting battery supplies.*
M. *Galvanometer.*
O. *Detector Valve.*
P. *4-cored Armoured Cable for battery supplies.*
R. *Aluminium Screening Case.*

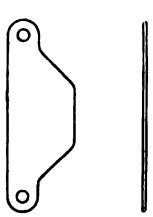

FIG. 3

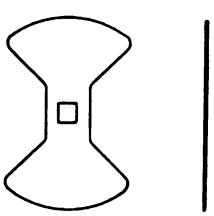

FIG. 4

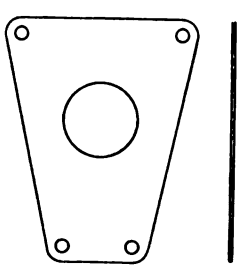

FIG. 5

through a suitable bearing in the Mycalex base, and on the underside of the base it is secured with the requisite degree of freedom by two nuts screwed on to the spindle. The driving shaft of the worm gear is brought out with its axis parallel to the base to the end of the aluminium case where in a cavity in the case the driving handle is secured to the shaft. This handle is shown in Fig. 1.

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The shape of the fixed and variable vanes of the variable condenser are shown in Figs. 3 and 4 respectively. Above the variable condenser is built the fixed condenser F. This again consists of brass vanes and air dielectric. The shape of these plates is shown in Fig. 5. At two points in each plate they are secured to the same brass pillars which support the fixed vanes of the variable portion, and two other pairs of stout brass pillars are supplied and fixed in the Mycalex base to support the other extremities of the vanes of the fixed condenser. These last two pairs of supports are larger than the first two pairs and are carried up through a second Mycalex plate which forms the top securing insulating plate of the condenser. Through a large central hole in each of the fixed vanes is brought the upper end of the shaft of the variable condenser and this shaft passes through a bushed central hole in the top Mycalex plate where it is secured by means of a bush screwed to the shaft. On the top Mycalex plate is the scale of the instrument, and on the shaft bush is the pointer.

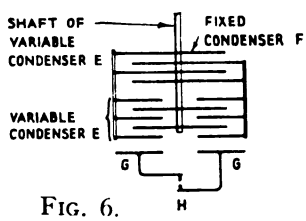

FIG. 6.

The scale is of silver plated brass. It is engraved with 110 divisions, of which 100 divisions subtend an angle of 90°. The pointer has 10 divisions which equal 9 divisions of the scale. One hundred divisions of the scale are active and represent the full angular travel of the condenser, the remaining 10 permanent vernier observations to be taken when an angle of more than 91 divisions of scale is exceeded.

The terminals of the complete condenser system are those of the fixed condenser which are connected to the fixed vanes of the variable condenser. The moving vanes are free of all connection, and in this way the troubles due to brush gear or flexible connection is entirely avoided.

Beneath the fixed vanes of the variable condenser and insulated by air from them are placed two small plates of brass. These are connected to the contacts of a small key whose insulated head protrudes through the left hand side of the case. These form the small balancing condensers and tapper key shown in Fig. 2. The contacts of this key are of 22ct. gold. This metal was adopted after repeated tests were made with various metals. A good contact at this point is imperative and gold proved to be superior for the purpose to all other metals, including platinum. Fig. 6 gives a general idea of the arrangement of these balancing condensers. It will be seen that when the contacts H are closed a capacity variation occurs in the total condenser owing to G.G. being connected together and placed near to a pair of electrodes of opposite sign. Stiff, wide, thick, plates of copper are run from the terminals of the complete condenser, on the lower side of the Mycalex base. At a part on each plate, a stout brass bush is connected to the plate, brought through and secured to the Mycalex base. This gives the position for the inductance J which is not a permanent fixture to the base but can be withdrawn and replaced by another as required by the frequency to be measured. The copper plates are then carried on to almost the extremity of the Mycalex base and still beneath it, where at a suitable position they are air insulated from and overshadowed by another pair of copper plates. These two pairs of plates constitute the coupling condensers D.D. and they have each a capacity of about 1 cm. The second pair of

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plates are carried on to the end of the base where by suitable means they are secured to a porcelain insulator, which insulator passes freely through a bushed screwed hole in the aluminium case and terminates with its face flush with the outside of the case. This insulator is fitted with two brass sockets connected to the second pair of plates and these sockets serve as terminals for the aperiodic coupling coil and cable.

The other apparatus mounted on the Mycalex base is the valve detector circuit. This is shown in Fig. 2, contained within the dotted rectangle and at the right hand end of the sketch. The detector circuit consists of a small square copper frame supported upon the base with its plane parallel to the plane of the Inductance J when the inductance is in position. One terminal of the frame connects directly to the plate of a triode, the other terminal of the frame connects to one terminal of a moving coil galvanometer 0 to 100, which represents 0·5 milliamp full scale deflection. The other terminal of the galvanometer connects to a metal socket of a porcelain insulator. Two other metal sockets in this insulator connect to the filament terminals of the valve and a fourth socket in the insulator connects to the grid of the valve. Small mica condensers of ·01 mfd. connect from the junction of the frame and galvanometer to the negative filament terminal and from the grid of the valve to the negative filament terminal. The porcelain insulator which is similar to that used for the feeder cable connection socket, is mounted upon the Mycalex base and passes through a similar screwed bush to that used for the feeder cable and terminates with its face flush with the surface of the aluminium case. The valve which is mounted in a holder on suitable copper supports lies with axis parallel to the centre line of the base and above it. In the end of the case a large hand hole is bored, so that the valve can be easily withdrawn when required, and into this hole is screwed a large metal dome to protect the valve from damage. The whole is mounted in the aluminium case, which is closed by an aluminium lid in which are cut 4 windows. It will have been noted that in the case are 5 apertures, 2 for connection purposes, one for tuning handle, one for balancing key and one for the valve protecting dome. The surfaces of all these holes and the top surface of the case have been very accurately machined so that when the top plate of the instrument and the appropriate fittings are screwed into position the screening of the apparatus is as perfect as the use of the instrument will permit.

The four windows cut in the lid cannot very well be closed by metal screens for the following reasons. One window is provided for the indicating galvanometer, one for an aperture to permit the withdrawal and refitting of the various inductances, one for scale and pointer, and one for the thermometer, which is secured in a perforated metal tube to the lid of the instrument. The aperture for the inductance removal is closed by a Bakelite cover plate which is fitted with two ball catches clipping into two sockets on the lid. This can be seen in Fig. 1. The reason for using an insulator and not a conductor for closing this slot is that if a metal plate were used, the screening and consequent accuracy of the instrument would depend upon the care with which an observer fitted the cover plate into position. As the total resistance of the screen would be changed with every removal of the protecting plate, it was considered advisable not to use metal, but to use an insulator so that this variable screening difficulty could be eliminated. In spite of the 4 apertures in the lid of the instrument the total screening of the apparatus is of a very high order.

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The aperiodic search coil and cable is shown in Fig. 7. It consists of a Bakelite former screw cut and wound with copper wire. A protecting tube and two end caps enclose this coil. No metal, other than the winding and cable is permitted in the construction of this coil and feeder, so that the chances of brushing are reduced to the minimum. A protecting insulating tube for use as a handle fits into the coil former and its covering and through this is passed a two core armoured cable, the ends of the conductors of which are soldered to the coil terminals. To the other ends of this cable are secured two metal pins which are held in a porcelain insulator. Also to this insulator is fastened a metal cone terminating in a male thread. Over this cone fits the armouring of the cable and it is secured in position by an internal cone with a female thread at the base, which screws on to the male thread of the previous cone. A solid metal cover, as shown in Fig. 8, envelops cones, insulator and plugs, and when the plugs are inserted into the sockets provided in the instrument and the cover screwed home, connection is made for the feeder cable, the armouring is earthed to the case, and the screening of the case at that point completed.

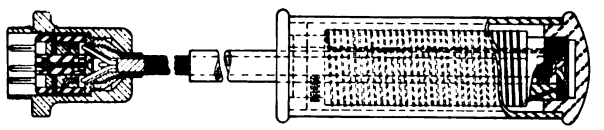

FIG. 7.

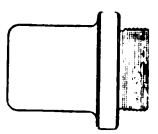

FIG. 8.

The same arrangement is used with the four core battery cable. This is not so long as the feeder cable, and its free end terminates in another porcelain insulator fitted with 4 metal sockets which connect to a 4-pin plug in the battery box. This insulator is covered with a Bakelite handle for ease in removal from the battery box. It is shown in Fig. 9 and can be seen in position in Fig. 1.

The battery box is a simple affair and is provided with all the necessary batteries for working the instrument. It is also provided with a series resistance for the filament of the valve, a milliameter-voltmeter with a range switch and a main switch. The diagram of connections of the battery box are shown in Fig. 10.

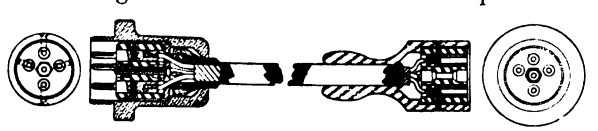

FIG. 9.

The battery in the box consists of dry cells, an extra cell being provided with a link for connection should the L.T. battery run down. The application of negative to the valve is arranged by switch. The whole is very simple in construction, and the battery box is copper shielded.

The only part of the complete instrument now to be described are the standard inductances of the measuring circuit. Whilst it was fairly easy to build a robust condenser with a small temperature coefficient, it was a more serious problem to construct a really sound inductance. Had a total disregard of weight and size been possible, the problem would not have been quite so difficult as it ultimately proved to be, where small dimensions were imperative. The relative advantages of the

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cylindrical coil and flat spiral having been considered it was decided that the flat spiral had advantages in compactness over the more common cylindrical coil for the purpose in hand. Tests showed that Ebonite as a base upon which to build the spiral inductance had considerable advantages over Bakelite from a sensitivity view point, but tests on the variation of inductance with temperature definitely proved that both of these materials were quite useless for the work in hand.

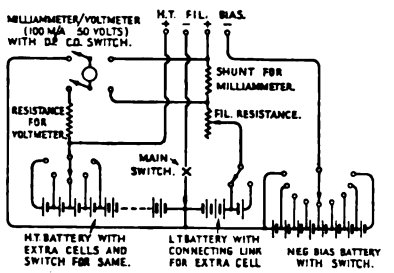
MILLIAMMETER/VOLTMETER (100 M/A 50 VOLTS) WITH D.P. C.O. SWITCH.
H.T. FIL. BIAS.
SHUNT FOR MILLIAMMETER.
FIL. RESISTANCE.
RESISTANCE FOR VOLTMETER.
MAIN SWITCH.
H.T. BATTERY WITH EXTRA CELLS AND SWITCH FOR SAME.
L.T. BATTERY WITH CONNECTING LINK FOR EXTRA CELL
NEG BIAS BATTERY WITH SWITCH.

FIG. 10.

A very large amount of work has been done to reduce the temperature coefficient of the inductance to the smallest possible amount whilst maintaining simplicity of design, low resistance and consequent accuracy of observation. This work has resulted in producing the inductances shown in Figs. 11, 12, 13, 14. The inductances essentially consists of a Mycalex sheet upon which the metal spiral is fastened at a number of points. Each Mycalex plate is fitted with two stout spring plugs and a third plain faced foot. The plugs are the terminals of the inductances and the plain foot is insulated.

There are four distinct models of this inductance. One, Type A, which is a plain wide single turn of copper, which is used for the highest frequencies, the second. Type B, is a flat spiral of $\frac{1}{4}$-in. pitch, which can be adjusted for frequencies rather lower than the first type, a third, Type C, consists of two plates, each similar in structure to the second type, mounted back to back with centre points connected and the outer ends of each coils brought to the terminals of the complete unit, and the fourth, Type D, is similar to the third but employs a spiral of $\frac{3}{16}$-in. pitch.

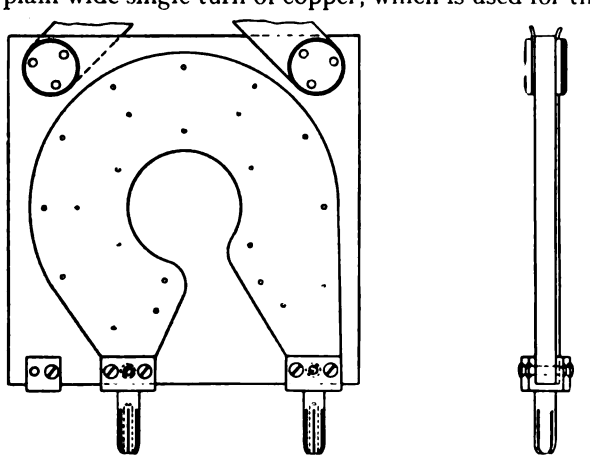

FIG. 11.

Each inductance is cut from a plain copper sheet, for it was known that any attempt to bend strip into a spiral would set up unequal stresses and strains in the metal and very probably considerably affect the temperature coefficient of the unit. The inductance in conjunction with its condenser can be adjusted to a frequency with considerable accuracy, and when once adjusted the copper is not removed from the Mycalex, but is left secured, the whole finely sand blasted and cold lacquered. The bases of the plug connections are engraved with the approximate frequencies at 10 and 90 divisions of scale, when the inductance

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is used with its specified instrument. The instrument number is engraved upon a brass plate and fixed in an upper corner of the Mycalex plate, and the range number engraved upon a similar plate fixed to the opposite corner. The two brass plates also secure a leather strap to the Mycalex plate which assists in the removal of the inductance from the body of the instrument.

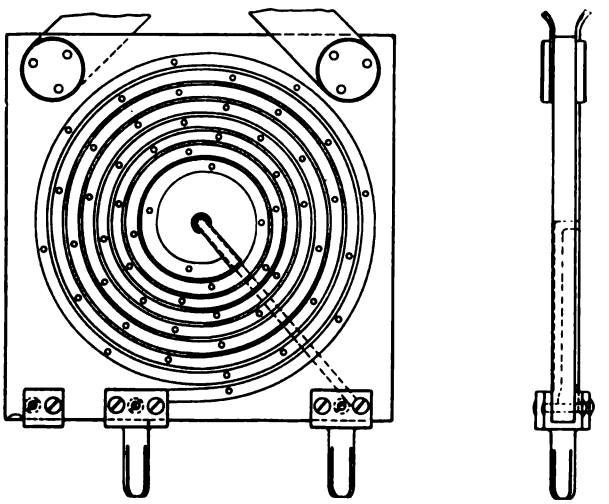

FIG. 12.

Mention has been made of a plain foot affixed to the Mycalex plate. The reason for this is as follows. In the Mycalex base of the complete instrument are fixed two heavy brass sockets into which the plugs of the inductance fit. These sockets are purposely not situated symmetrically about the centre line of the instrument in order that no error can occur in fitting the inductance to the main body. It was found that a certain amount of misplacement of the inductance could occur on account of the plate being rocked about the plug nearest to the centre line of the

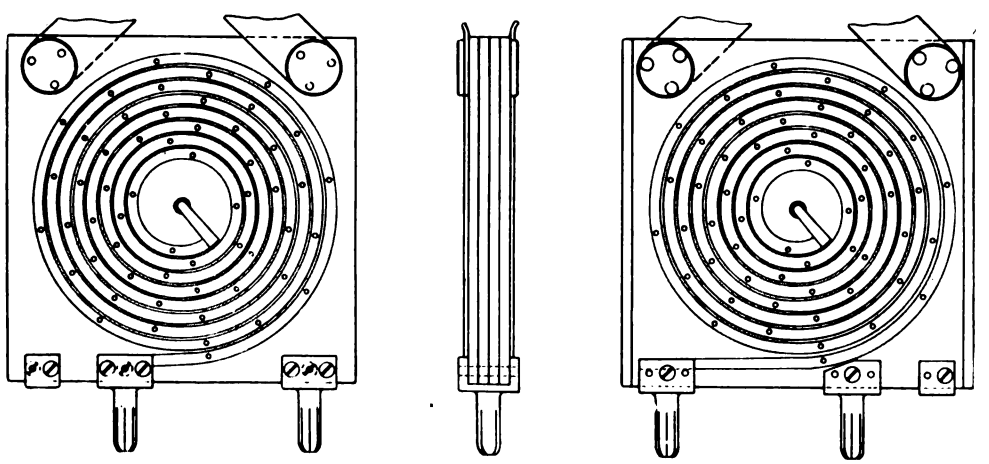

FIG. 13.

plate. Therefore in the Mycalex base of the main body a small brass plug was fixed and this and the face of the two sockets carefully reduced to a common level, and

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on the inductance Mycalex edge a plain brass foot was fitted, which with the faces from which the plugs stand was also brought to a dead level. The result is that the plugs of the inductance fit into sockets provided for them and the metal projections on the edge of the inductance plate engage at 3 points with 3 points on the main base. Tests, on the withdrawal and refitting of an inductance from and to the main

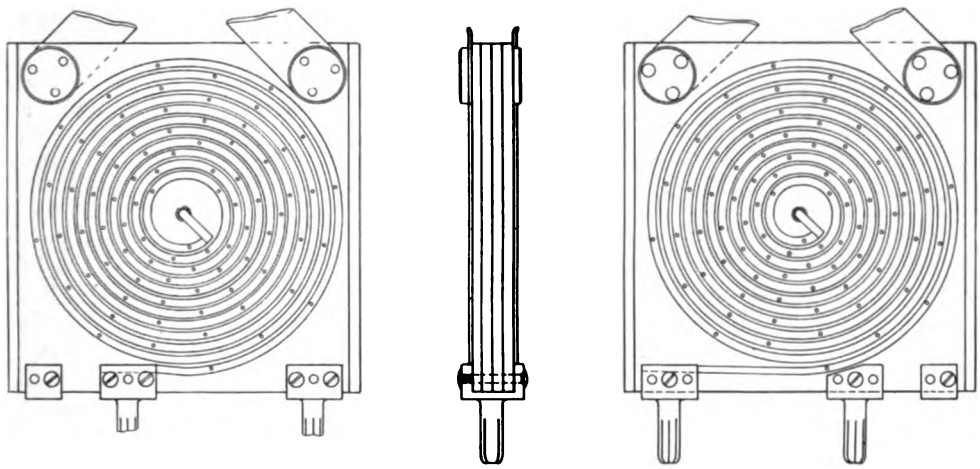

FIG. 14.

body, have shown that an error of 1 in 25,000 is of the order of inaccuracy to be expected, and as this figure is without the appreciation of the instrument it can be neglected. It should be mentioned here that in the aluminium case of the instrument are fitted two channelled Bakelite guides into which the inductance plate slides. The plate is definitely a very loose fit in the channels and is not intended in any way to grip or support the plate, for it has been found that if the plate is subject to any restraining influence, then great errors can be introduced by these influences. The plate must stand free of everything except the two plugs and their feet and the third plain foot. The object of the channels is for ease in locating the inductance plate with respect to the base and to prevent damage in removal. The foregoing describes in some necessary detail the items comprising the complete instrument, and sufficient has been stated to give general reasons for the lines upon which development has taken place. It is now necessary to give some idea of the performance of the instrument. As the term wavelength conveys little information to anyone in present day radio work and as frequency means a great deal more, it was therefore decided to calibrate the instrument in frequency and not in wavelength. Further, as the frequency varies inversely as $\sqrt{C}$. the pointer of the condenser is fixed in such a position that the lowest scale indication is also the lowest frequency of any particular range. The instrument was originally intended to cover a frequency band of 3,000 kc. to 30,000 kc. and to have a difference of 5 kc. per vernier division at the highest frequency. Overlaps between ranges had to be considered, and therefore if a useful scale length of 750 vernier division per range was allowed the number of ranges to cover the total band would not be too great, and each pair of adjacent ranges would not be separated by a gap. Now if the assumption is made that

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characteristic of the instrument is a straight line over 750 vernier divisions of scale, and if U is the upper and L the lower limit of the total band of frequency to be measured in kilocycles, and the discrimination is 5 kc. per vernier division on the highest range, the

$$U = L\left(\frac{U}{U - 750\times5}\right)^N$$

where N is the number of ranges of the complete instrument.

$$30{,}000 = 3{,}000 \times \left(\frac{30000}{26250}\right)^N$$

N = 17·24 and the factor $\frac{30{,}000}{26250}$ = 1·1428 is the range factor per scale of the instrument assuming that the self capacity of all inductances used are equal one to the other and are small enough to be neglected. The assumption that the frequency increases uniformly per vernier division is of course incorrect, and in any case it is unsatisfactory, for if at the highest frequency of the highest range the discrimination is 5 in 30,000, *i.e.*, 1 in 6,000, then at the lower limit it becomes 5 in 26,250 or 1 in 5,250.

Assuming that the value of the condenser increases equally from point to point and that the range of frequency remains the same then the discrimination varies from 1 in 4,900 at the highest value of frequency to 1 in 6,500 at the lowest value of frequency in a range.

This second arrangement is also rather unsatisfactory for the accuracy of discrimination per vernier division is not equal throughout the range. The ideal arrangement is the one in which $\frac{d_2 - d_1}{d_1}$ is a constant for the whole range where d_1 is the frequency at a certain vernier scale position and d_2 is the frequency at the vernier division adjacent and superior to d_1.

If $\frac{d_2 - d}{d} = \frac{1}{6000}$ 30,000 kc. is the highest frequency to be measured and 750 vernier division is the useful width of a scale we get as the lower limit of that scale.

$\left(\frac{5999}{6000}\right)$ 750 × 30,000 = 26,492 kc. and the fraction $\frac{30000}{26492}$ = 1·1324 becomes the new range factor. The use of this factor, of course increases the number of ranges to 19 as a minimum to cover the total band from 30,000 kc. to 3000 kc.

Such is the ideal case, but in actual practice there is one factor which definitely prevents the ideal from being obtained over more than one range, unless very elaborate precautions are taken. The factor is the self capacity of the inductance and as this cannot easily be maintained identical in all inductances the characteristic of the various ranges of the instrument must vary somewhat. In spite of this it has been thought desirable to modify the variable portion of the tuning condenser so that the frequency characteristic of the final instrument approaches the ideal. The alteration is simple and merely affects the shape of one plate of each fixed bank of the variable condenser.

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In practice it will generally be found that the discrimination of the instrument is of a higher order than the figure of 1 in 6000, for the self capacity of the inductance shortens the frequency band per range and so gives a higher accuracy. This is however an advantage in the majority of cases.

The temperature coefficient of the instrument has been touched upon, but it may be of interest to give a few figures relating to the 4 types of inductance used.

	Approximate frequency band.		Temp. Coeff.
Type A.	30000—18750 kc.	..	± 1 in 25,300 per ∓ 1 deg. cent.
Type B.	18750— 5580 kc.	..	± 1 in 27,400 per ∓ 1 deg. cent.
Type C.	5580— 2955 kc.	..	± 1 in 24,000 per ∓ 1 deg. cent.
Type D.	2955— 2239 kc.	..	± 1 in 20,000 per ∓ 1 deg. cent.

The foregoing figures indicate the order of the temperature coefficient, but these will vary with different instruments on account of the slight inherent differences in the materials used. As the instrument is calibrated at a definite temperature, after standing at that temperature for not less than twelve hours, and is checked at another temperature after being kept at this second temperature for a period of twelve hours ; and as the temperature coefficient is stated upon the frequency chart, the observer need have no fear in using the instrument and applying the temperature correction.

The calibration of the instrument is done under almost ideal conditions, and every care is taken to ensure the accuracy of the results.

In a previous paper the fundamental Marconi method of determination of frequencies has been described. Since the date of that paper further developments have taken place, and in some cases a tuning fork now replaces the alternator as the standard of frequency. Although the greatest precautions are taken in maintaining the tuning fork constant in temperature to 0·01 deg. cent. and the electric supplies to the driving valves are kept to a very high order of constancy, it is not to be supposed that the frequency of the fork is blindly accepted as constant for the purpose in hand. The tuning fork frequency is referred to the alternator at least twice per day when in use so that any change of the order of 1 in 100,000 can be determined. This is costly, but certainly worth while.

It has been stated that the instrument is kept at constant temperature during calibration. To do this it has been necessary to build a calibration tank. A large outer steel tank contains a smaller steel tank and the inside of the smaller steel tank is heavily lagged with thick felt and wood. Between the two tanks water circulates. Two thermostats, one for high and the other for low temperature, are fitted in the inner tank. Electric heaters are contained in the inner tank which are operated by the thermostat in use via a relay. A fan driven by a motor external to the tanks keeps the air in circulation in the inner tank. The whole is closed by a heavy wooden top lagged internally. In this top are two close fitting glazed doors which are normally locked and through which the instrument to be tested can be lowered into the tank. Various small handles protrude through glands in the tank for the tuning of the instrument under test. In calibration the instrument is placed in the tank with the aperiodic coil and its cable protruding through its appropriate gland.

Calibration is done by coupling the search coil of the frequency meter to the output inductance of a screened oscillator and powerful double magnifier circuit.

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Each stage of this system is effectively screened from all other stages, and the result is that the application of the search coil to the output circuit does not in any way affect the frequency of the oscillator. The actual measurement of the frequency is made by the methods described in the previous paper, using an electrically maintained fork instead of the alternator. The instrument is brought into resonance with the oscillator by simple tuning by means of the main tuning handle of the condenser. This is rotated until the galvanometer indicates the maximum deflection. The key at the left hand side of the instrument is now depressed, and as this action introduces a small condenser to the tuning circuit of the frequency meter, the galvanometer deflection is reduced. Tuning by the main driving handle and detuning by the balancing key continues until the deflection of the galvanometer with the key depressed is equal to the deflection of the galvanometer with the key released. The pointer of the instrument now indicating a certain scale value this is taken as being the indication of the known frequency of the oscillator.

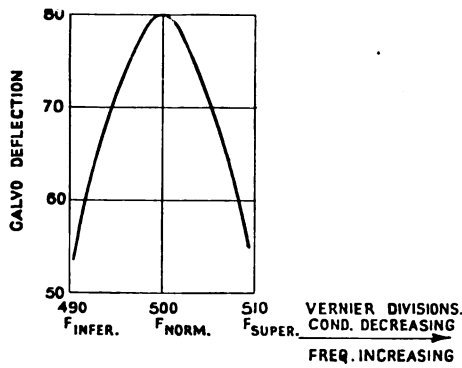

FIG. 15.

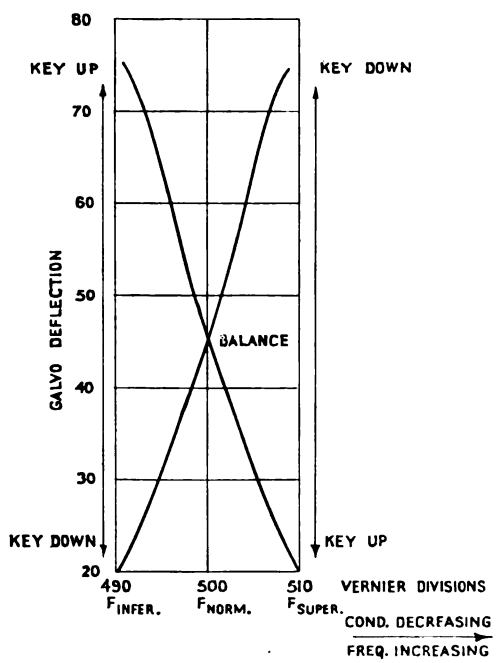

FIG. 16.

The explanation of this tuning and detuning condenser is simple. In Fig. 15 is shown an actual characteristic of condenser value in scale division against galvanometer current, keeping the frequency constant and varying the instrument. It will be seen that this curve is rather flat topped. When the instrument is in tune with the oscillator and the detuning condenser is introduced the galvanometer current is lessened owing to the circuit being out of resonance with the oscillator. If now the main tuning condenser is decreased a point will be found where the addition of the detuning condenser places the main tuned circuit slightly out of tune with the oscillator on the one side and the removal of the detuning condenser again places the tuned circuit slightly out of tune but on the other side of the resonance point of the circuit. When these two out of tune positions are equally placed about

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the point of resonance, the rectified currents in the valve circuit are equal and the balance points are symmetrically disposed about the point of resonance. This is the condition of balance and the foregoing explains the use of the tapper key and balancing condensers. The reason for the use of this detuning and balancing system is as follows. Fig. 15 shows the characteristic of galvanometer indication against condenser setting in the ordinary manner. It will be seen from this that misplacing the condenser by one vernier division at maximum deflection gives a

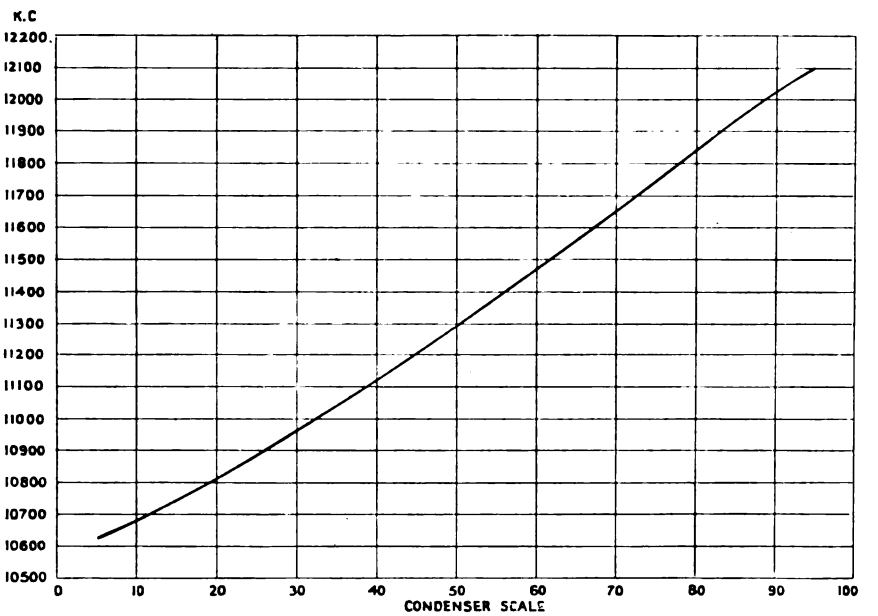

FIG. 17.

change of galvanometer current of about ·5 of a scale division, but Fig. 16 shows the case where the detuning and balancing condenser is used, and from this it will be seen that a misplacement of 1 vernier division of the condenser upsets the galvanometer indication by no less than 3 divisions about the point of balance, and in consequence, in spite of the fact that the galvanometer deflection is not so great as in the more simple case, the accuracy of the complete instrument is made considerably greater by the use of the detuning and balancing system.

The balancing system is not at all difficult to use. The method of using the instrument is as follows. The correct range coil being fitted, with the search coil in position and the battery connected and switched, the search coil is presented to the circuit to be measured and the instrument tuned to full galvanometer deflection. Balancing then proceeds until the down and up positions of the detuning key give the same galvanometer deflection. The scale and pointer is now read off and referred to the chart of the instrument from which the frequency can be abstracted. Correction for temperature can also be made. As the instrument is of a portable type it was thought that a curve might be inconvenient to the user, therefore charts similar

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to the well known logarithm table are supplied. These charts give main division and tenth of division from 5 to 95 divisions of scale and the frequency for each 1/10 division is printed in the chart. Curves if required are of course available, and such a curve on a very much reduced scale is shown in Fig. 17.

Fig. 18 shows the calibration of the tuning condenser of the instrument. This is measured when the condenser is in its case, as the metal body of the case, of course, has some effect upon the capacity of the instrument.

Tests have been made to find to what extent the proximity of large masses of metal influence the instrument. As the instrument is calibrated in a metal tank it can be taken that this is an extreme condition. A calibration was made in the

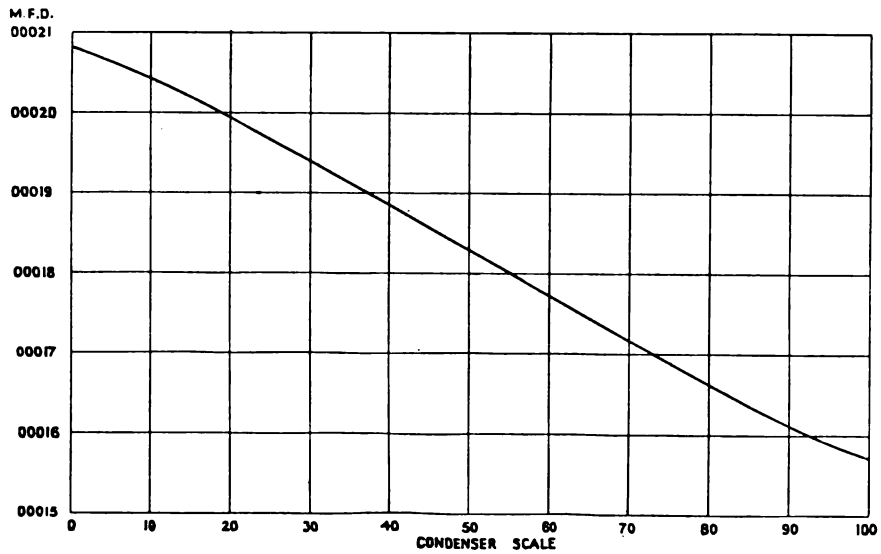

FIG. 18.

tank at a given temperature. The instrument was then removed to a position remote from metal bodies and returned and recalibrated by alternator, and the temperature correction applied.

The result of this test showed that no difference of any magnitude appreciable by the instrument existed after temperature correction was made.

As a further test the instrument was taken to the well known B.B.C. station 5 SW and the frequency of that station measured by the instrument. At the same time 5 SW on an unmodulated dash was measured at the laboratory by alternator. The results showed an error of 1 in 25,500, which is without the appreciation of the instrument. This test was of further interest. It was expected that sufficient stray field from the transmitter to indicate on the instrument would be present and the instrument was set with full negative bias to prevent damage to the galvanometer, but it was actually found that with this bias the search coil of the instrument had to be presented to the closed circuit of the last stage of the main amplifier before the

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instrument was sufficiently operated. This gives an idea of the screening of the instrument.

The valve used as a detector is the Marconi D.E.3. This valve is very suitable for such an instrument as the one described, for its filament current is only 60 m/amps. at 2·8 volts, and its characteristic when connected as shown in Fig 2 is steep enough to give a sharp rise in plate current for small impressed voltages. By using this valve a dry cell battery can supply all the necessary voltages, and this removes the troubles of charging and acid creeping which are always found with secondary batteries.

Changes of voltage on the valve do not make any detectable change in the accuracy of the instrument, although, of course, the galvanometer current varies with the voltages applied to the valve.

Changes of valves of the same type do not impair the accuracy of the instrument, although, here again, the galvanometer current will vary with different valves.

It has been stated in the earlier portion of this article that the discrimination of 1 in 6,000 was the desired figure. This figure has been somewhat exceeded in certain cases, owing to the capacity of the inductance and a typical case may be quoted where, in the instrument for which Fig. 17 is the characteristic the discrimination between 100 and 850 vernier divisions can be obtained from the following table. For the purpose of allowing for overlaps between ranges the band between 100 and 850 vernier divisions is taken as the useful portion of the scale.

Division.	Frequency.	$\frac{d_2 - d_1}{d_1}$	Discrimination per Vernier Division
100 (d_1)	10,680	$\frac{1\cdot2}{10680}$	1 in 8900
101 (d_2)	10,681·2		
200 (d_1)	10,815	$\frac{1\cdot4}{10815}$	1 in 7725
201 (d_2)	10,816·4		
300 (d_1)	10,963	$\frac{1\cdot5}{10963}$	1 in 7308
301 (d_2)	10,964·5		
400 (d_1)	11,121	$\frac{1\cdot6}{11121}$	1 in 6950
401 (d_2)	11,122·6		
500 (d_1)	11,288	$\frac{1\cdot7}{11288}$	1 in 6640
501 (d_2)	11,289·7		
600 (d_1)	11,466	$\frac{1\cdot8}{11466}$	1 in 6370
601 (d_2)	11,467·8		
700 (d_1)	11,648·5	$\frac{1\cdot9}{11648\cdot5}$	1 in 6131
701 (d_2)	11,650·4		
800 (d_1)	11,835	$\frac{1\cdot9}{11835}$	1 in 6223
801 (d_2)	11,836·9		
849 (d_1)	11,928·1	$\frac{1\cdot9}{11928\cdot1}$	1 in 6288
850 (d_2)	11,930		

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Here may be given another Table, from which ranges per type of inductance, whether A, B, C or D, can be derived for an instrument covering the entire band of frequencies.

TYPE A.
Range Factor, 1·134 approx.
Total Range, 30,000 to 18,750 kc. approx.
No. of ranges, 4 approx.

TYPE B.
Range Factor, 1·12 approx.
Total Range, 18,750—5588 kc. approx.
No. of ranges, 12 approx.

TYPE C.
Range Factor, 1·108 approx.
Total Range, 5588 to 2955 kc. approx.
No. of ranges, 6 approx.

TYPE D.
Range Factor, 1·106 approx.
Total Range, 2955—2239 kc. approx.
No. of ranges, 3 approx.

This Table should not be taken as inflexible, as it is merely the result of measurements taken and cases will occur where it will be more convenient to depart from the Table than adhere to it, and variation can, of course, be made to suit individual requirements.

It will be noted that Type B inductance is fitted to more ranges than any other type. This is simply a matter of convenience as Type B is easier to adjust than Type A and simpler to construct than Types C or D.

The weight of the instrument with one inductance, aperiodic coil and battery load is 56 lbs. 8 ozs. The weight of the battery box is 31 lbs. 8 ozs., and the weights of the inductances vary with type between 2 lbs. 9 ozs. and 4 lbs. 9 ozs.

The foregoing is a brief description of the Company's Precision Frequency meter, the use of which it is thought will assist in keeping the present day high frequency transmitters to their respective channels.

T. D. PARKIN.

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WIRELESS TELEPHONY AND DIRECTION FINDING IN THE FAR SOUTH

PART II.

The first part of this article, which was published in THE MARCONI REVIEW, *No. 15, dealt with the general conditions of service that wireless apparatus for use in the Whaling Industry has to meet.*

This discussion is continued below, and the article concludes with an account of the advantages attending the use of direction finders on Whaling Vessels.

THE majority of whale-catchers are built in either England or Norway, and most of them have to proceed without an escort from the builders' yard to the fishing grounds in the Antarctic, a distance of from 7,000 to 8,000 miles. During this long and lonely voyage these very small boats are liable to get into very tight corners due to adverse weather conditions causing a shortage of bunkers, stores, water, etc., and as the wavelength of their standard wireless telephone installation is fixed at a spot wavelength between 300 and 400 metres, they would in the event of emergency be unable to communicate with shipping, which normally employ a wavelength of 600 metres. In order to provide for such an emergency, the Marconi Company have introduced into their 1930 " Whaler " Telephone Sets an additional spot wavelength of 600 metres which can be brought into immediate operation by means of a single switch, so that in the event of a whaler being in difficulties during the voyage from Europe to the Antarctic, the Master of the vessel can immediately get into touch with neighbouring shipping or a commercial coast station and thereby secure assistance.

It is the general rule for whale-catchers to return to Europe every two or three years for overhaul and Lloyd's Survey, and during this homeward voyage and the subsequent outward voyage the 600 metre wavelength can again be employed.

Another advantage of this addition is that it gives the gunner an alternative wavelength for inter-ship telephonic communication when on the fishing grounds so that if interference is experienced on the lower wavelength a change can be made to the 600 metre wave and the communication maintained.

Reports received from the whaling fleets show that considerable difficulty is sometimes experienced on the fishing grounds due to the interference caused by the transmissions of a number of whaleboats which have been fitted with wireless telephone and telegraph installations manufactured by other wireless companies. Investigation proves that this interference is due to the fact that these transmitters use direct coupled aerials, with the result that their tuning is extremely flat. It is

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worthy of note that not a single complaint has been received that the Marconi telephone sets cause interference to receivers not tuned exactly to the transmitting wavelength. This is undoubtedly due to the fact that the Marconi "Whaler" transmitters have loosely coupled aerials, which result in the tuning being extremely sharp.

Marconi 500 *Watt Telegraph-Telephone Set with Adaptor for* 600 *m. wave installed at Prince Olaf Harbour.*

In 1927 tests were carried out with the co-operation of the British Post Office, with a view to ascertaining what range could be obtained between a trawler fitted with a Marconi $\frac{1}{4}$ kw. Telephone Set (X.M.D. 1), and a British commercial wireless coast station. During these tests, which were carried out in summer time during daylight, reliable telephonic communication was maintained with the General Post Office coast station at Grimsby up to a distance of 250 miles, and at this distance messages were transmitted to the owners of the trawler.

A few months after these successful tests a Marconi type X.M.C. 1 telephone set was installed in a radio station on the Humber, which is now available for telephonic communication with any vessel working on a wavelength of 220 metres. Reports received show that this station is capable of communicating with trawlers up to a distance of 300 miles and this range is frequently exceeded.

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In passing it is of interest to note that the National Lifeboat Institution have recently equipped a number of their lifeboats with Marconi " Whaler " telephone sets of the X.M.B. 1 type, so that the coxswains of the lifeboats can keep in touch with the various lightships and coastguard stations around the British coast, which were fitted some years ago with Marconi telephone apparatus.

Various Governments have also purchased a number of X.M.C. 1, X.M.D. 1 and X.M.B. 1 telephone sets for point to point telephonic communication and these transmitters are giving a service equal to and in many cases superior to the land line service previously employed, which, owing to the nature of the country, or damage to the under-sea cable, had frequently been subject to interruption.

Prince Olaf Harbour, South Georgia.

With the introduction of wireless telephony into the whaling industry, it was not long before the whaling crews realised the possibilities of wireless direction finding as a valuable aid to the industry, and in 1926 a number of important whaling companies requested the Marconi Company to fit their catchers with direction finding apparatus. The Marconi Company developed a special direction finder suitable for installation on small whale-boats, where it would be subject to very rough handling and severe climatic conditions.

From the experience gained during the installation of the wireless telephone sets during the previous year, it was evident that a direction finder which was complicated in operation would be of no value to the whaling fleets, and would

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in fact be a menace, owing to the possibilities of the whaling crews making faulty adjustments which would result in very inaccurate bearings being taken.

To enable the reader to thoroughly appreciate the value of the direction finder to whaling fleets it is necessary for one moment to study the method employed in whale chasing.

Whale Catcher with whale lashed alongside.

A steam trawler leaves her base and proceeds in search of whales. Immediately the "blow" of a whale is sighted, the vessel is steered in that direction, and the speed increased to approximately 14 knots. Before the vessel has gone very far on this course the whale will have sounded, and will eventually appear in a totally different direction, with the result that the course of the vessel has to be again changed. During a long chase the whale will sound twenty or thirty times, each time coming up in a different position, with the result that in order to get close enough to the whale to shoot, the course of the whale-catcher will have to be changed probably twenty to thirty times. During the excitement of the chase no records are ever kept of these alterations in course, with the result that when the whale is eventually captured the gunner is very uncertain as to the actual position of his vessel. Before the introduction of the wireless telephone and direction finder, if the gunner found that the whale was drawing him too far away from his base, he had to give up the chase owing to the difficulty he would experience in finding his way back. All of this has now been altered, as when the gunner desires to return he immediately gets into communication with his base by means of the wireless telephone, and requests them to transmit for one or two minutes in order that he can obtain a bearing with the aid of his direction finder, and thereby ascertain the exact course to steer to return to his base.

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With the aid of the direction finder it is always possible for the catchers to find their way back to their base, even in very foggy weather.

An example of the enormous value the wireless direction finder has already proved to the Antarctic whaling fleets is the sinking of the whaling mother-ship, "Southern Queen," on the 24th February, 1928. This vessel at the time was cruising some distance from the South Orkneys in the Antarctic, and on the morning of February 24th had despatched her whale-catchers in search of whales. Some time after the catchers had left and were out of sight, the mother-ship "Southern Queen" struck an iceberg, and immediately began to sink. The Marconi wireless telephone set with which she was fitted was immediately put into use, and calls transmitted to the catchers recalling them to her assistance. These distress calls were immediately picked up by the catchers, who forsook their whales, and immediately started back at full speed to the assistance of their mothership. Unfortunately, visibility was very poor about this time, and in order to assist their return the catchers requested the operator of the mothership to keep transmitting so that they could use their direction finders and find their way back without delay. This the operator of the mothership did until ten minutes before his ship sank, when, together with the other members of the crew, he was compelled to take to the lifeboats. A quarter of an hour after the sinking of the "Southern Queen" the catchers arrived on the scene, and picked up the lifeboats, thereby saving the whole crew.

The valuable aid which the wireless telephone and direction finder had proved during this unfortunate episode demonstrated to all the whaling companies the great advantage of wireless, with the result that it has been universally adopted among the whaling fleets of the world.

In the polar regions, owing to varying magnetic influences, the ordinary magnetic compasses are often very unreliable, and subject to large errors. The use of the wireless direction finder overcomes this difficulty, as courses and positions can be repeatedly checked by means of the wireless direction finder, which is not influenced in any way by magnetic variations.

During recent years wireless direction finders have been fitted on a large number of British and foreign fishing trawlers, where they have proved of enormous value in assisting trawlers to find their way back to port during adverse weather conditions, and also in locating the position of other trawlers fishing in productive areas.

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THE UNIFORM SHORT WAVE AERIAL

The subject of phased short wave aerials, both for broadcast and beam transmission, is, in certain respects, still capable of further development. The uniform type of aerial to be described below has so many undoubted advantages over the older types, that the latter are being replaced by the uniform type of aerial throughout all the Marconi beam stations.

A large increase in signal to noise ratio from stations changing over to the use of uniform aerials has been almost universally noted, and other considerations enumerated in the following article indicate that this aerial represents a notable advance in short wave aerial design.

IN the design of aerials for short wave communication, it is very important to consider the way in which the aerial under consideration distributes its radiated energy in the vertical plane. It has been proposed to use aerials which radiate their energy upwards in order to take advantage of the reflection from the Heaviside layer, and it is essential that we should know in what directions aerials of various types radiate their maximum power.

If we assume that the power source or excitation point of the aerial is at the base of the aerial, the energy beam may be taken as diverging from this point. The analysis of the distribution of this energy near the aerial itself is of little importance compared with the distribution at points far removed from the aerial. This region may be taken to mean that zone in which the electric and magnetic intensities are in phase and equal, and has been termed the " Wave Zone."

The intensity of the energy beam can be calculated and plotted as a function of the polar angle and is called a " distribution diagram " to distinguish it from the " polar diagram," which is the distribution diagram at points near the aerial.

The angle that the direction of maximum radiation makes with the earth varies, of course, with the value of l/λ, where l is the length of the vertical aerial, and λ is the operating wavelength.

If we take the case of a simple vertical half wave aerial, and if we assume the earth to possess perfect conductivity, we shall see that the polar diagram of such an aerial has a maximum value in a plane which is at right angles to the aerial and which passes through the centre of the aerial. Hence we should expect the vertical polar diagram of such an aerial to be as shown in* Fig. 1. If we take into account the fact that the earth is not perfectly conducting, the absorption by the earth of the rays propagated horizontally is so great that all these lower rays are more or less

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* " Short Wave Wireless Telegraphy." T. L. Eckersley, Journal I.E.E. Vol. 65, No. 366. June, 1927.

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completely absorbed and we are left with a diagram of the form shown in Fig. 2, in which the dotted curve represents the effective radiation.

We know that in long wave working the waves can be considered as travelling in a plane horizontal to the earth's surface at any point, and hence in long waves we should require to concentrate the energy in a horizontal plane. But with short waves, owing to the very high earth losses, the horizontal part of the wave known as the direct ray is quickly attenuated to a negligible amount, as pointed out above, and cannot therefore be used for long distance communication as is the case with long waves. It is most probable that for nearly all long distance work, *i.e.*, over 2,000 miles, the most useful radiated energy is that which leaves the transmitting aerial system at a zenithal angle of between 5° and 15°, the angle increasing for shorter distance work until it becomes so large that the ray, instead of being reflected or retracted by the Heaviside layer and so returning to earth, penetrates the layer and is lost. For very short distances, therefore, we have to rely on the direct ray for communication. Thus, for long distance communication we require an aerial system which projects most of its energy at a zenithal angle of something between 5° and 15° from the horizontal. The approximate distribution diagrams of different type aerials on short wavelengths are shown in Fig. 3. These are actually drawn for Franklin aerials in which the radiation from alternate half wavelengths is suppressed, but we shall see later that they are applicable to the uniform aerial.

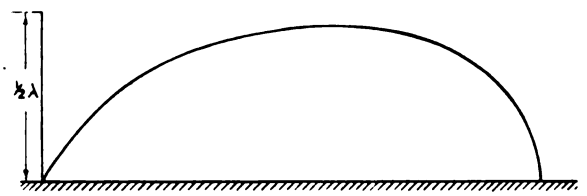

FIG. 1.

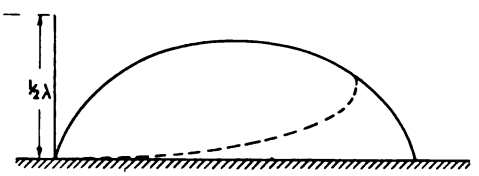

FIG. 2.

The following inferences can be made :—

(1) A short vertical aerial with loading to give a node of potential at the earth gives a maximum radiation in a plane inclined at an angle which increases as the distance from the transmitting aerial increases, and finally attains some constant value at great distances. This angle is reduced when the aerial becomes a half wave aerial with its lower end near earth.

(2) If the length is increased to multiples of half a wave length without phasing devices, thus forming what is known as an harmonic

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aerial, the radiation produced is all high angle, because each successive half wavelength oscillates in anti-phase and the effective radiation at shallow angles is very greatly reduced.

(3) If one adds a series of half wave aerials vertically so as to oscillate in phase, the zenithal angle of maximum radiation is reduced, and such a system gives a concentration of energy in directions which are more efficient for short wave working.

In beam aerials used prior to the uniform aerial, the radiation from alternate half wavelengths was wholly, or in part, suppressed, to ensure that the resultant radiation at a point far removed from the aerial should be the sum of the fields of radiation due to currents in the same direction, and hence that the radiation from the adjacent parts of the aerial should be additive and should not tend to cancel each other.

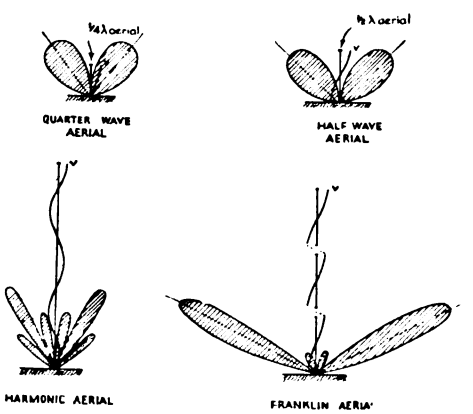

FIG. 3.

The uniform aerial, however, has for its principal object the attainment of strongly marked directional qualities without any substantial suppression of radiation. In this aerial, which is long relative to the wavelength employed, the currents are mechanically reversed in direction at alternate half wavelengths, the arrangement being such that the radiation from these sections of the aerial is added to that of the remaining half wavelengths.

In one form of construction, a vertical aerial is formed with its first or lowest half wavelength as a simple vertical wire. The second half wavelength proceeds for a distance equal to ·1 of a wavelength as a prolongation of the first half wavelength, after which it turns through a right-angle and proceeds in a perpendicular direction for ·05 of a wavelength. It is then bent through a second right-angle and extends down through ·2 of a wavelength, after which it turns from a third right-angle proceeding in a direction perpendicularly away from the first half wavelength through a further ·05 of a wavelength. Finally, it is bent again through a right-angle and proceeds upward through its final ·1 of a wavelength. The third half wavelength is formed as a vertical prolongation of the last portion of the second half wavelength. The fourth half wavelength is formed in a similar manner to the second, except that it proceeds towards the vertical line in which the first half

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wavelength lies, instead of away from it. This construction is continued as is shown in the diagram.

By making the length of the wire between centres of adjacent sections of the aerial greater or smaller than half a wavelength, a progressive change of phase between sections may be obtained. Maximum radiation may thus be obtained in directions substantially different from the direction at right angles to the aerial.

The aerials designed on the above basis are illustrated in Fig. 4, in which (*a*) represents an aerial in which alternate half wavelengths are suppressed, and (*b*), (*c*), (*d*), (*e*) and (*f*) represent modifications to the uniform type of aerial.

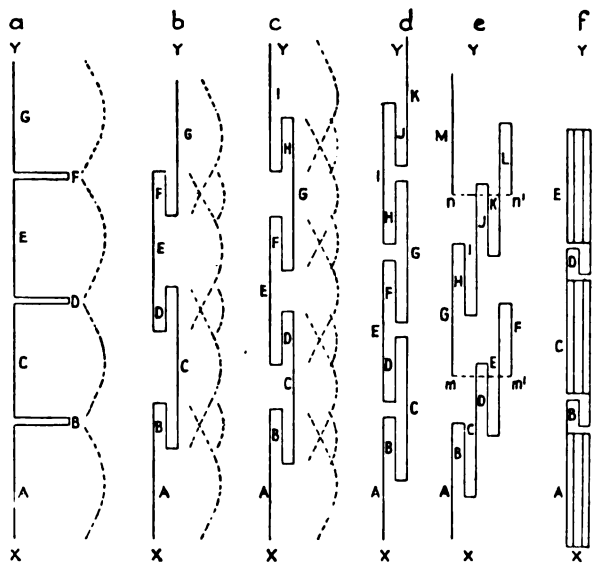

FIG. 4.

The simplest form is given in (*b*) where the sections B, D, F are caused to radiate, and owing to the reversal of the direction of the wire, assist the radiation from the sections A, C, E and G.

If equal currents are induced in (*a*) and (*b*), (*b*) will give approximately $\frac{5\cdot2}{4}$ times the field strength given by (*a*).

The advantages of the uniform type of aerial over the previous types employed may be stated as follows :—

(1) Substantially the whole length of each vertical unit is employed to produce radiation, instead of alternate half wavelengths as previously used.

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(2) For the same height the radiation per unit current of the aerial is very much increased, which means that for equal radiation, smaller voltages and smaller currents are required in the new uniform type.

(3) The radiation from the aerial is substantially uniform throughout the whole vertical extension instead of being more or less concentrated at points about half a wavelength apart. The result is that the new uniform type has far less tendency to produce large loops of radiation in undesired directions in the vertical plane.

(4) By adjusting the lengths of the folded back portions of the aerial, the angle of the beam in the vertical plane can be easily controlled, and the aerial can be specified for any definite angle in the vertical plane which may be desired.

(5) The radiation of the aerial can be made substantially uniform throughout the whole linear extension or can be made to follow any desired law, and this again has marked effect on the size of the loops of radiation in undesired directions in the vertical plane.

(6) The practical construction presents a more uniform surface to the wind, as in the older type concentrated masses appeared about every half wavelength.

Comparison of results obtained with standard multisectional and uniform type aerials.

Comparative tests between the two types of aerials were carried out in the period between February 26th, 1929, and April 18th, 1929, on the normal programmes radiated from G5SW, the short wave experimental broadcast station developed and erected at Chelmsford by Marconi's Wireless Telegraph Company for the B.B.C.

In analysing the results given below, two points should be borne in mind. The first is that the majority of the reports were sent in by amateurs, and possess, therefore, varying amounts of statistical reliability, and the second is the fact that the two aerials were not in absolutely identical positions as regards surrounding metallic objects, etc., although particular care was taken to ensure that differences in radiation due to this cause were reduced to a minimum.

The uniform aerial was supported from a triatic wire at a height of 250 ft. from the aerial feeder box, and the multisectional aerial was supported from the same triatic at a height of 350 ft.

Both aerials hung vertically and were connected to the transmitter by similar beam copper tube feeders.

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The tests covered the whole daily programme time, 12.30 to 13.30 G.M.T., and 19.00 to 24.00 G.M.T., thereby ensuring various conditions of light and darkness. The change from one to the other aerial being made at each half hour and occupying not more than 30 seconds.

ANALYSIS OF REPORT.

Locality.	Favourable to Uniform Aerial.	Favourable to Standard Multisectional Type Aerial.
U.S.A. } Canada }	69%	31%
Australia } New Zealand }	80%	20%
Europe	90%	10%
South Africa	75%	25%
India	50%	50%
Egypt } Sudan }	100%	—
Malta	100%	—
East Africa	100%	—
British Guiana	100%	—
China } Hong Kong }	85%	15%

The quick change-over lessened the chance of reports being affected by any appreciable alteration in conditions.

In view of the definite superiority of the uniform aerial the programmes radiated from G5SW since April 30th, 1929, have been carried out entirely on the uniform aerial.

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MARCONI VETERANS' SECOND ANNUAL REUNION DINNER

At the inaugural dinner held on the 29th November, 1928, Marchese Marconi was the host, and his guests were men of "The Old Brigade," who had served with the Marconi group of companies for 25 years or more.

On the present occasion the old brigade—who had in the meantime adopted the name of "Marconi Veterans"—acted as host to Marchese Marconi.

THE Dinner was held at The Royal Adelaide Galleries, Strand, W.C. 2, on Saturday, December 14th, 1929, with Col. H. Jameson-Davis, the Founder in 1897 of the Wireless Telegraph and Signal Co.—the original Marconi Company—in the Chair.

Sir Ambrose Fleming and 48 other veterans attended, and telegrams expressing good wishes and regretting their inability to be present were received from Mr. H. W. Allen on the S.S. "Naldera," in the Indian Ocean, Mr. Hayburn, Brussels, and Marquis Solari, Paris.

Col. H. Jameson-Davis.

The Chairman, Col. H. Jameson-Davis, said that he was very pleased to propose the health of their honoured guest, Marchese Marconi, his very distinguished relative, who was not only the inventor of wireless communication which had proved its utility over land and sea, but had so often helped the Marconi Company through difficult periods by some timely new discovery, such as the beam system, and now we were informed that at no long distance of time power may be transmitted without wires as messages are now sent by telegraph and telephone.

He referred to the work done by the veterans in the early days, and mentioned Sir Ambrose Fleming and Mr. G. S. Kemp, and expressed sorrow at the loss during the year of their old friend Mr. Holloway.

It was with much regret that he had heard the news of the death that day of Admiral of the Fleet, Sir Henry Jackson, an old personal friend, and one of the early believers in the Marconi system, who worked wireless successfully on his own ship.

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Marchese Marconi in his reply said :—

" I wish to thank Col. Jameson-Davis for the very kind things he has said about me and my work, and the achievements of us all—I particularly appreciate them coming from him, for as we all very well know, Col. Jameson-Davis was the founder of the Marconi Company. Had it not been for his faith in wireless, and in me, there might have been no Wireless Company formed in 1897 ; and although I believe that wireless was nevertheless bound to come, its development might have been very seriously prejudiced and delayed, and the lead which this country gained, and, as I believe, still retains over all others in wireless communication, might well have been lost.

The Marchese Marconi, G.C.V.O., LL.D., D.Sc.

" Our Company, which was the first ever to be formed for working wireless, is also, I may say, a very rare example of a pioneer Company not only successfully surviving, but also remaining a pioneer Company.

" There are those of us here who represent what have been, and still are, the leaders of this Company, especially on its technical side, and if we have also been able to prove to the world more and more as time went on that radio communication to the more distant parts of the earth was no mere idle dream, but a reality, not only serviceable and practicable, and in some cases, essential, but also commercially profitable—that, I submit, has been no mean achievement.

" Gentlemen, it is a very great pleasure for me to be able to see so many of you here to-night—so many who have survived the trials, the vicissitudes, and the turmoils, not only of this mortal life, but also of the Marconi Company. I think it can justly be said—and even with all due modesty—that had it not been for you who are now present, and all who have worked with us, including those who, alas ! are no more—this Company would never have been able to realise what has constituted an undreamed of extension, I may say a beneficient revolution of the means of communication between human beings.

" With the comparatively recent development and practical application of the Beam system, we have once more proved that our initiative and our vitality are undiminished.

" Gentlemen, I wish to thank you with all my heart, not merely for your hospitality in asking me to partake of this very excellent dinner, but above all for

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giving me the still greater pleasure of again meeting here to-night so many of my friends, and so many of those who, for over a quarter of a century, have loyally co-operated with me in the carrying out of what is surely a great work."

Marchese Marconi then paid a tribute to the late Mr. Holloway, and also took the opportunity of this occasion to say that he would always gratefully remember the kindness and assistance he received from Admiral Sir Henry Jackson when demonstrating his invention to the Admiralty on his first arrival in this country, and later, on ships under the command of Sir Henry.

Sir Ambrose Fleming, M.A., D.Sc., F.R.S.

Sir Ambrose Fleming on being called upon to speak, remarked on the pleasure it gave him to be present at the second of these Marconi Veterans Dinners, and said that probably not all present were aware of the interesting electrical history connected with the building in which they were then assembled. It was originally built in 1830 as a place for stimulating an interest in popular science and called after the Consort of King William IV. "The Adelaide Gallery of Practical Science." Model steam engines, oxy-hydrogen, microscopes, and other scientific novelties of that day were exhibited for public instruction and entertainment. Amongst other things it possessed a sample of a live electric eel or *gymnotus* and the visitors amused themselves by getting shocks from it. Faraday was desirous of discovering whether its electricity was identical with that furnished by the Voltaic pile and electrical machine, and by permission carried out many experiments here with it, which are detailed in the Second Volume of his *Experimental Researches*.

He caused the shock of the animal to deflect a galvanometer, and used it to magnetise a sewing needle. He also employed it to decompose iodide of potassium and even obtained from it an electric spark, thus proving that its discharge was a genuine current of electricity and not any spurious imitation of it.

Here also in this Adelaide Gallery, Sir Charles Wheatstone made his classical experiments in the velocity of electricity in wires and showed them to many people. William Sturgeon, the inventor of the electromagnet was a frequenter of the gallery, and having heard here from a Mr. Peaboddy of Joseph Henry's experiments in the United States on the self induction of wires, was led to experiment on the subject himself, and so made an induction coil which provided one of the essential elements for the early progress of wireless.

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1895

Marchese G. Marconi

1896

G. S. Kemp

1897

Col. H. Jameson Davis. H. W. Allen. J. Cave.

1898

P. W. Paget. C. E. Rickard. R. F. Cave.

1899

W. Densham, Andrew Gray, H. M. Dowsett, R. T. Munson,

F. S. Stacey, F. Woodhouse, C. S. Franklin, P. J. Woodward,

1900

R. N. Vyvyan, A. J. Clark. F. Archer, J. Harvie Clark,

Sir Ambrose Fleming, A. H. Atkinson, E. E. Triggs,

1901

W. S. Entwistle, W. J. Willey, G. H. Green, H. W. Corby, A. Eve,

Capt. C. V. Daly, G. Pells, E. G. Tyler, F. E. D. Pereira, F. K. May, A. H. Girman,

1902

E. Berry, W. F. Thomas, R. D. Bangay, F. E. Burrowes, W. Davies, Capt. H. J. Round,

H. A. Ewen, R. G. Kindersley, A. A. Kift, J. Lewis. A. B. Blinkhorn, F. J. Leathers,

1903

D. W. Tullock, J. R. Stapleton, F. Jones. J. Harvey.

A. J. Huff, H. T. Worrall, E. T. Hills,

1904

H. J. Tattersall, A. J. Irvine, T Iddon, W. A. Taylor, W. I. McGhee,

F. L. Dennis. J. R. Robinson. H. F. White, W. Platt, W. J. Collop,

W. N. Ball, F. S. Hayburn, P. L. Rowland, A. Cappelaere.

H. Cornwall—1904

Marconi Veterans' Scroll, 1929, on the reverse of the Reunion Programmes.

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Later on, when an indifferent public failed to give it sufficient support as a home for popular science, the Adelaide Gallery was converted into a dancing saloon and devoted to the worship of the goddess of the twinkling feet. Finally when that failed, it was acquired by Messrs. Gatti, and became this noted restaurant. Hence it would hardly have been possible for the Committee to select a place for the dinner in honour of the inventor of wireless telegraphy, the Marchese Marconi, more appropriate than the Royal Adelaide Galleries, made notable by its association with the work of Faraday, Wheatstone and Sturgeon.

It might even be appropriate, said Sir Ambrose, if the Marconi Veterans Dinner were always held in this restaurant.

In conclusion he begged permission to wish them all a pleasant Christmas and a very happy and successful New Year.

Other speeches by Mr. G. S. Kemp, Mr. G. H. Green, and the Joint Secretaries, Mr. H. M. Dowsett and Mr. C. E. Rickard followed, and after a musical programme, the proceedings terminated.

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February, 1930

G. Marconi

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General Editor: W. G. RICHARDS.

WORLD WIDE COMMUNICATIONS WITH SHORT WIRELESS WAVES*

BY T. L. ECKERSLEY, B.A., B.SC. AND K. W. TREMELLEN.

In this article the conditions which control short wave long distance communication are discussed, certain problems of short wave propagation are experimentally attacked, and the method of applying the knowledge so obtained in projecting new services is given.

For convenience the article is divided into three parts :—

(1) *A summary of modern transmission theory.*
(2) *Experimental results obtained from a 12-months' interception of short wave wireless signals.*
(3) *Practical application of the results obtained from the above to the projection of new services.*

It should be noted that the subject matter on pp. 15, 16 and 17 is an addition to the original article.

Modern Transmission Theory.

IN modern transmission theory it is recognised that the upper ionised region of the atmosphere known as the Heaviside layer, plays a predominant part.

Radio research has given us a comprehensive, if not yet very accurate, picture of the nature of this layer. The region is conducting on account of its ionised state. The ionisation in the daytime is almost certainly produced by the sun's ultra violet radiation, and extends down to heights of approximately 80 km. above the earth's surface, but at night time the ions in the lower parts of the layer rapidly recombine and leave the higher regions ionised down to heights of 100 to 130 km.

The ionic density N according to the most recent experiments, rises to a maximum of about $N=10^5$ at 100 km. height, dies away, and then increases again to values rather greater than this at 240 km. above which height very little is known.

The mean time between the successive collisions of an electron with the molecules of the air is a critical factor in determining the behaviour of the waves in the medium,

* This article is a summary of the paper read before the "World Engineering Congress" held at Tokio in October, 1929.

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for if the electrons can move freely and make many oscillations in the time between collisions, the behaviour is determined by Eccles theory of ionic refraction, and obviously applies to all short wave transmissions of frequencies greater than 3 by 10^6 (or wavelengths less than 100 m.).

The conditioning factors at any point in the layer are (1) the ionic density N ; (2) the gradient of the density $\frac{\delta N}{\delta h}$ and (3) the collision frequency $\frac{1}{\tau}$.

The essential conditions for long distance transmission are, firstly that the rays shall be sufficiently bent round the curvature of the earth, and secondly, that the attenuation along the path shall be sufficiently small.

The failure of any signal to " stay the course " can be attributed to the failure to satisfy one or other of these conditions.

With regard to the ray bending, the relations which follow from the theory may be expressed thus :—

Let N maximum be the maximum density which occurs at a height h, then the shortest wave that will be sufficiently bent to come down to earth is given by

$$\lambda^2_{\min} \cdot \frac{Ne^2}{\pi m} = \frac{2h}{R} \text{ approx.}$$

$$\text{or } \lambda^2_{\min} = \frac{2h}{R} \frac{\pi m}{Ne^2}$$

Shorter waves than this escape from the earth and travel into outer space.

The attenuation constant at any point of the layer where the density is N, the collision frequency $\frac{1}{\tau}$, e and m the charge and mass of an electron, and c the velocity of light, is $\frac{Ne^2\lambda^2}{\pi m c \tau}$ and is jointly proportional to the ionic density N, the square of the wavelength λ^2, and the collision frequency $\frac{1}{\tau}$.

It will be observed that if two signals of wavelength λ_1 and λ_2 follow the same path, the relative attenuation of the two will be proportional to the squares of their wavelengths.

If we could specify the values of the quantities N, $\frac{1}{\tau}$, and $\frac{\delta N}{\delta h}$ at every point on the path of a ray between the transmitter and receiver we should have the data necessary for computing the signal strength received per kw. radiated.

These quantities, which measure the state of ionisation of the upper layer above a given point on the earth's surface, depend essentially on the local time at

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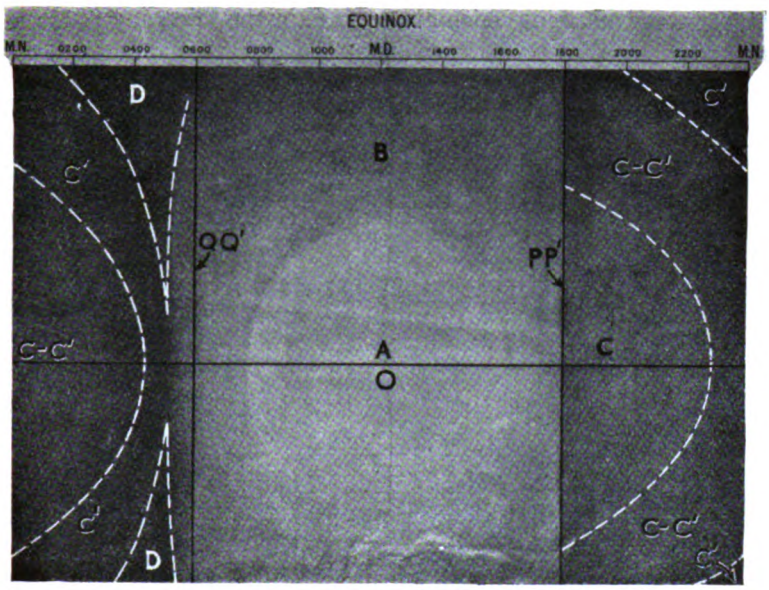

FIG. 1.

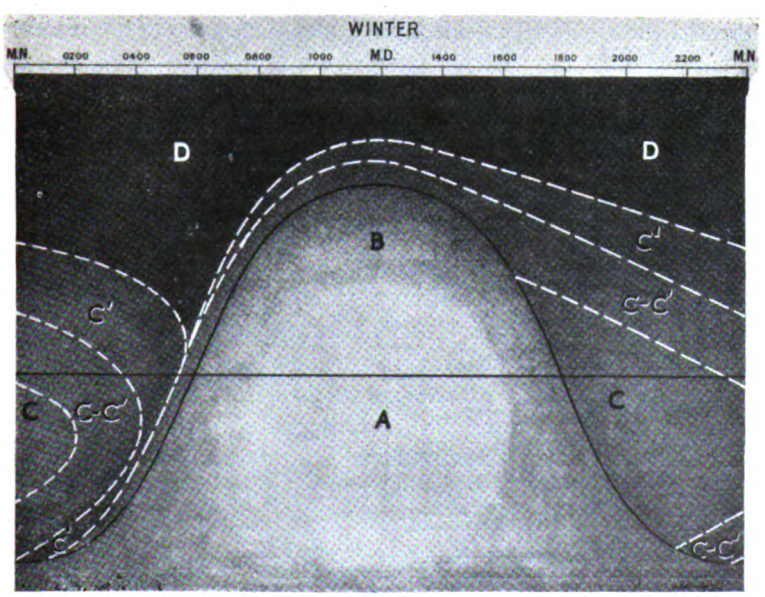

FIG. 2.

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that point, for the ionisation, which at any rate in the lower layers is produced by the sun's ultra violet radiation, depends on the sun's position angle and therefore on the local time.

The transmission between any two points on the earth's surface will have a regular diurnal cycle as the earth revolves below the layer, the characteristics of which remain constant relative to the sun's position. Such diurnal cycles have, of course, been observed on the transmission characteristics of all sufficiently distant stations.

For the purpose of specifying the condition in the upper atmosphere we have to prepare charts of it giving these quantities relative to the sun's zenithal position.*

Strictly speaking a triply infinite series is required to give these three quantities at every level in the Heaviside layer. This being obviously impracticable, we have to be content with a single chart which may be interpreted to give the condition along the route of any path with sufficient definiteness to allow predictions to be made.

By marking off the regions in various grades, we can obtain an estimate of the total attenuation along any route. In compiling the chart the continuous series of observations has been most useful and we have brought to it all our knowledge obtained from all sources, whatever they may be.

The construction of the chart may be explained with reference to the theory as follows :—

To represent the whole Heaviside layer or conducting layer 80 to 200 km. above the earth's surface on a flat chart, a Mercator's projection is used. The simplest representative case is that drawn for the equinoxes. In this case the sunset and sunrise lines (the division between light and darkness) are meridians, and are represented PP and QQ (Fig. 1). The region between these two is illuminated by the sun's rays and outside them is in darkness. Figs. 2 and 3 give similar charts drawn for mid-winter and mid-summer respectively in our hemisphere.

Use of Shadow Charts and Map.

The conditions of light and dark on any route may be obtained at any season and at any time by placing the chart (which in practice should be printed on transparent paper so that the map underneath can be easily seen) corresponding to the season required over the map, with the line marked Equator on the chart coinciding with the Equator on the map and with the time as shown in G.M.T. at the top of the chart, against the arrow drawn through the Meridian of Greenwich. Thus taking the Winter chart Fig. 4 as an example, it will be seen that at midday G.M.T. the route to Capetown is almost entirely in intense daylight. The route to India is entirely in twilight, and of the two routes

* Note that the conditions at any point in the upper atmosphere only depend on the position of this point relative to O, and are independent of the rotation of the earth below the layer.

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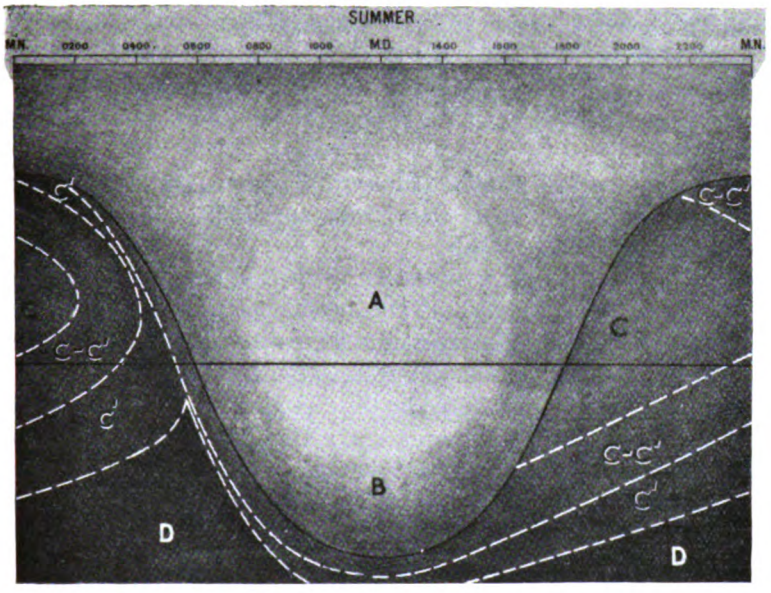

FIG. 3.

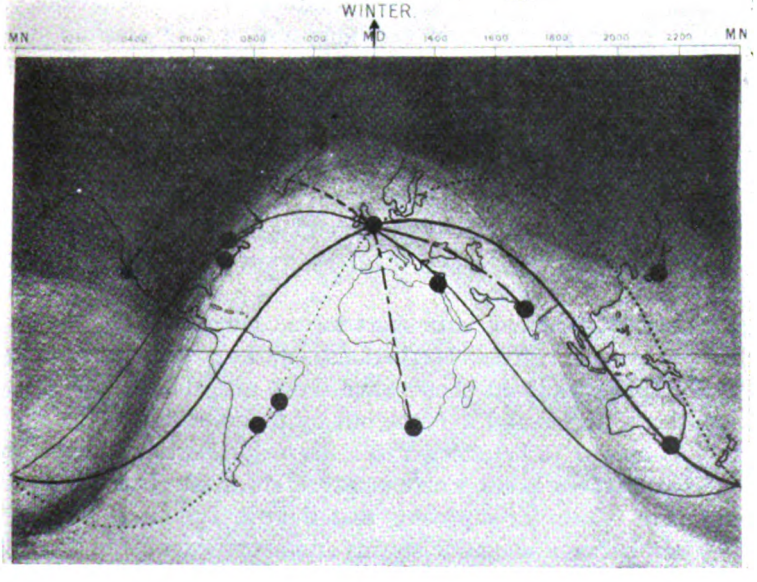

FIG. 4.

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to Australia, that via India traverses a mixture of twilight and early or tropical night, whilst that via the Pacific passes through twilight bordering on the intense daylight, followed by twilight near the shadow band, then a small portion only of late night darkness (as it is Summer in the Southern Hemisphere) and finally a small portion of Summer darkness. An illustration of the chart and map combined is shown in Fig. 4.

In the latter part of this paper examples will be given of the use of these charts in explaining the vagaries of short wave communications.

Direction Finding and Scattering.

It has been tacitly assumed that except in the case of scattering the rays follow the great circle paths on the globe and the development and use of the short wave direction finding apparatus have enabled us to state with certainty that this is actually so for long distance transmissions in all but exceptional cases.

A new factor scattering, discovered by the direction finder is not of major importance in determining signal strengths except within the skip distances, where the illumination consists wholly of scattered radiation. It has, however, a very profound effect in the blurring of signals, and sets a limit in many cases to high speed transmission. Where signals are largely scattered they will arrive at the receiver by devious routes, the signals by the longer paths arriving later than those by the direct path. This results in a lengthening and blurring of the Morse marks. Signal retardations due to scattering of 0·01 sec. and more are known, and will completely blur high speed morse.

The most direct proof of scattering was obtained from the behaviour of the local English Beam Stations observed at our receiving station at Chelmsford, near London. It was noticed that these stations gave quite well defined bearings which were not the true bearings. Thus, for instance, the Bodmin (W. England) beam sending to South Africa gave approximately the bearing of Capetown. Similarly, Bodmin sending to Montreal gave approximately the Montreal bearing, etc. This peculiarity can be best explained by the analogy of a searchlight. A closed in searchlight will reveal itself chiefly by the light scattered from the region where the beam illuminates the clouds. In the same way the source of energy from the beams is the point where they enter the scattering layer.

Magnetic storms play havoc with short wave communication.

An extended series of regular observations is of the greatest value in determining the statistical relation between short wave fades and magnetic storms. Such a relation undoubtedly exists and is borne out by observations.

The services appear to be affected in a degree proportional to the nearness of their paths to the magnetic poles, where magnetic storm effects are most intense, but this gives an added reason for supposing that there is a physical relation as well as statistical relation between magnetic storms and short wave fades.

Experimental Results.

Continuous interception of short wave wireless signals between 15 and 50 metres

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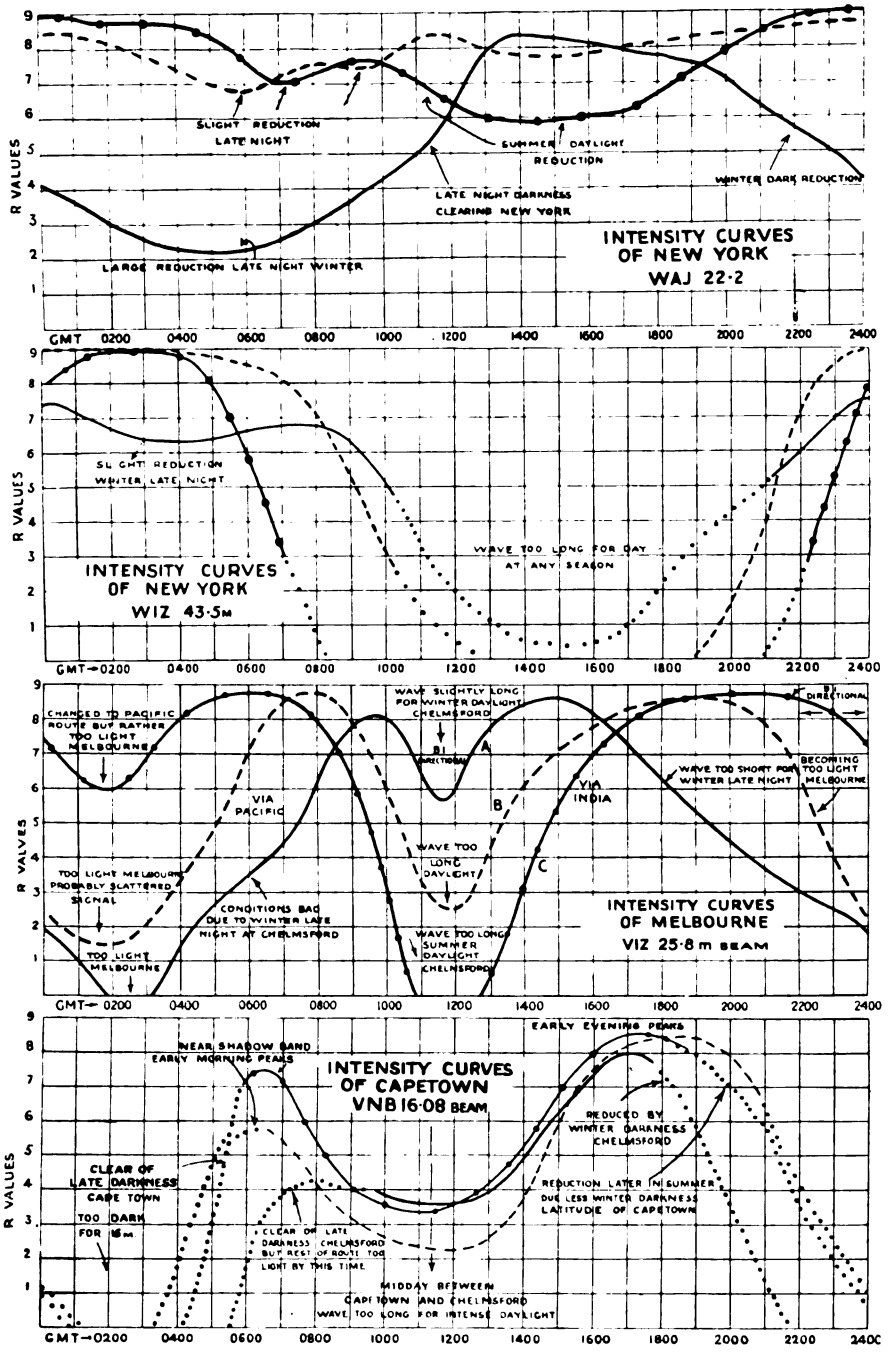
R VALUES
GMT 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400
SLIGHT REDUCTION LATE NIGHT
SUMMER DAYLIGHT REDUCTION
WINTER DARK REDUCTION
LATE NIGHT DARKNESS CLEARING NEW YORK
LARGE REDUCTION LATE NIGHT WINTER
INTENSITY CURVES OF NEW YORK
WAJ 22·2
SLIGHT REDUCTION WINTER LATE NIGHT
WAVE TOO LONG FOR DAY AT ANY SEASON
INTENSITY CURVES OF NEW YORK
WIZ 43·5M
CHANGED TO PACIFIC ROUTE BUT RATHER TOO LIGHT MELBOURNE
WAVE SLIGHTLY LONG FOR WINTER DAYLIGHT CHELMSFORD
BI DIRECTIONAL
VIA PACIFIC
VIA INDIA
WAVE TOO SHORT FOR WINTER LATE NIGHT
BECOMING TOO LIGHT MELBOURNE
TOO LIGHT MELBOURNE PROBABLY SCATTERED SIGNAL
CONDITIONS BAD DUE TO WINTER LATE NIGHT AT CHELMSFORD
WAVE TOO LONG DAYLIGHT
WAVE TOO LONG SUMMER DAYLIGHT CHELMSFORD
TOO LIGHT MELBOURNE
INTENSITY CURVES OF MELBOURNE
VIZ 25·8 m BEAM
NEAR SHADOW BAND EARLY MORNING PEAKS
EARLY EVENING PEAKS
INTENSITY CURVES OF CAPETOWN
VNB 16·08 BEAM
REDUCED BY WINTER DARKNESS CHELMSFORD
CLEAR OF LATE DARKNESS CAPE TOWN
TOO DARK FOR 16m
REDUCTION LATER IN SUMMER DUE LESS WINTER DARKNESS LATITUDE OF CAPETOWN
CLEAR OF LATE DARKNESS CHELMSFORD BUT REST OF ROUTE TOO LIGHT BY THIS TIME
MIDDAY BETWEEN CAPETOWN AND CHELMSFORD WAVE TOO LONG FOR INTENSE DAYLIGHT

FIGS. 5, 6, 7 & 8.

——— WINTER. —•—•— SUMMER. – – – – EQUINOX. ••••••••• CALCULATED.

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was carried out from October, 1927, to October, 1928, using a simple type of receiver.

The strength of signals was estimated by ear, and graded in strength of from R1 to R9. At the end of each month curves were prepared for each station embodying all the signal strength values obtained during the month. The curves then represented the average values of signals from that station for the month.

The curves, Figs. 5 to 8 inclusive, have been chosen to illustrate typical effects of light, dark and seasons. The reasons for the various forms taken by the curves are given on the curves, and can be made clearer by the use of the map and shadow charts

In addition to the observations on signal strength, direction finding apparatus was used from time to time to study the directional properties of signals received from long distance and nearby stations.

Conclusions from Twelve months observations.

Signal intensity apart from abnormal conditions is dependent on *distance*, and *light and dark conditions*, the latter being dependent on latitude and seasons. Land and sea effects are probably only noticeable on the direct surface ray which is only received up to comparatively short distances.

As regards distance, the "skip" effect either partially or entirely eliminates the reflected main ray signal over a distance depending on the wavelength and the light and dark conditions existing at the time. When signals are received in the "skip," observations by means of the direction finder show that they are either scattered uniformly from all parts, or more or less definitely from a particular source or sources at which the scattering conditions are best at the time. In cases where communication is confined to the daylight area in which the sun's altitude is more than about 30 degrees, the distance appears to vary inversely as the square of the wavelength. The table gives the approximate distances at which signals ceased to be audible on various wavelengths on the simple receiver used during the tests. These distances apply to the daylight area just mentioned.

TABLE I.

APPROXIMATE DISTANCES IN MILES AT WHICH SIGNALS CEASE TO BE AUDIBLE.
INTENSE DAYLIGHT ROUTE. FOR APPROXIMATELY 10 KW.

Wavelength in metres.	Distance in miles.
15	12,000
20	7,000
25	4,500
30	3,000
40	1,500
50	900

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As regards light and dark the case becomes more complex. It should be pointed out that previous to the commencement of the year's interception, day and night conditions had been assumed to be either light or dark or half light half dark. It soon became obvious, however, that to account for various effects noticed in the variation of signal intensity, it was necessary to divide the daylight and the darkness into grades depending on the altitude of the sun in the case of daylight, and on the latitude and the time after sunset in the case of darkness.

In order to illustrate this more clearly, reference should be made to the Shadow Charts, Figs. 1, 2 and 3. Taking Fig. 1 for the Equinoxes as the simplest case, the light and dark conditions which exist at the Greenwich times shown at the top of the chart are approximately shown in six grades, A,B,C, c-C',C', and D. The horizontal line represents the Equator, the vertical line QQ' sunset, and the vertical line PP' sunrise.

The gradation of the shaded areas has been obtained from a study of the behaviour of signals at various times and on various wavelengths.

For simplicity only six grades of light and dark have been taken, but it should be understood that the intermediate grades exist especially in the night period. The border line of grade A gives approximately a line on which the sun's altitude is about 30 degrees. This grade again for simplicity is shown as a single grade but the effect of the sun's rays is more marked at the centre than at the edge of this circle. The gradation of the light and dark thus obtained from the year's observations is also shown in Figs. 2 and 3 for winter and summer conditions in the Northern Hemisphere, and it will be seen that in winter due to the long nights, grade D predominates. The gradation is really an indication of the ionic density existing at the time, the darker the grade the less the density, and from signal strength observations, the minimum density is reached about an hour before the sunrise. For this reason grade D ends about an hour before the sunrise line on the charts.

It should be pointed out that although the daylight grade A is shown for simplicity as a circle, due to the Mercator projection used, lines of equal altitude of the sun's rays are only true circles near the centre of grade A. The true form of grade A as shown at the equinoxes is an ellipse with major axis North and South. In the summer months in the Northern or Southern Hemisphere this ellipse opens out somewhat to the East and West in high latitudes extending into the polar regions. Due to the fact that very few communication routes pass through the polar regions, our observations on the light and dark conditions existing there are limited.

The effect of light and dark may be briefly stated as follows :—

GRADE A.—*Intense Daylight.*

On the longer waves the attenuation is great, and waves below about 18 m. are necessary for long distance communication through this grade. Even on the

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shorter waves about 15 m. attenuation is appreciable when the route is of great length and traverses the centre of grade A.

GRADE B.—*Twilight.*

The attenuation on all waves is reduced, particularly on the shorter waves where it becomes extremely small.

GRADE C.—*Summer and Tropical darkness, excepting late night.*

The attenuation on all waves during the early portion of grade C is extremely small, but during the later portion, in grades CC′ and C′, the short waves below about 20 m. are reduced although the waves above about 20 m. are not affected to the same extent.

GRADE D.—*Winter darkness existing during the whole night in polar latitudes and all but the first few hours of the night in middle latitudes in winter.*

When the ray path traverses this type of darkness, the attenuation on wavelengths of 50 to 100 metres is small, but all signals below about 50 m. are reduced in strength. The reduction is slight above 40 m., but becomes considerable as the wavelength is reduced, until below about 24 m., signals are frequently inaudible, and no signal is received below wavelengths of about 18 m. The reason for the reduction of short wave signals in grade D, and in the intermediate grades between grade C and grade D is probably due to a lack of sufficient bending of the rays.

In this connection, it should be mentioned that the effects of darkness in reducing the signal strength of the shorter waves applies chiefly to any communications taking place over routes entirely in darkness. There appears to be no doubt from observations that in those cases where the transmitting and receiving stations are in daylight or twilight and the late or winter darkness exists only en route the effect of the latter is greatly minimised. In other words, if the bending is sufficient at both transmitting and receiving stations, signals are enabled to traverse the darker grades. The cases in which such conditions can occur are rather limited, but a good example is found when the transmitting station is near the border of grade A and the receiving station is at a point opposite to it also on or near the border.

In such a case, signals are frequently partially or entirely received by the longer dark route in spite of the fact that considerable distances on this dark route are through winter or late night which would reduce or possibly render inaudible, signals between two stations situated actually in that darkness. In the case just mentioned, echo signals would be heard on wavelengths short enough to permit a signal to traverse the highly attenuating shorter portions of the route across grade A, and providing the wavelength was not too short for the long dark route at the same time. *Echo signals* also frequently occur when the great circle route lies along or near the shadow band. In cases where the route passes in and out of the shadow band, the extent

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of the echo dependent the light conditions on one side and the dark conditions on the other side. The study of echoes is very complex, and is not entered into in detail. The reasons for some echo effects have still to be explained. From 30 to 40 metres echoes only occur when the route lies very near or along the shadow band, as the attenuation for these longer waves becomes too great on the daylight or twilight portion of any route crossing the shadow band.

Quick Echo Signals.

Quick echoes of the order of one-hundredth to one-twentieth of a second are frequently heard and appear to be usually caused by the arrival at slightly different times of two or more signals from various scattering sources, or of a main ray reflected signal and a scattered signal, or of a direct surface ray and a scattered signal. This type of echo, of course, has no connection with the round-the-world echoes.

Signal Strength within the "Skip."

As might be expected the diurnal and seasonal changes occurring on scattered signals from a station within the " skip " depend upon the conditions existing on the routes traversed by the scattered signals. If signals from a beam station within the " skip " are scattered back from a distance of a thousand miles in Grade A they will be attenuated on passing through Grade A, on a total route out and back of two thousand miles. Similarly, if the scattering route is in late darkness or Grade D, probably because the edge of the skip is at a great distance at that time, very little energy is scattered back. The signals scattered back from the Dorchester beam directed on New York which traverse out and back, much the same route traversed by the New York beam directed on London, show a marked similarity in diurnal and seasonal changes to the curves for this New York Station.

Magnetic Storms and Sun Spots.

Fig. 9 shows some effects of magnetic storms on signal intensity, and some records of fade out periods observed during the year combined with records of intensity of magnetic disturbances.

An attempt has been made to connect fade out periods with magnetic storms and sunspots, and although in a number of cases the connection has been very definitely established, cases do occur of magnetic storms and sunspots with no accompanying fade out, and fade outs have occurred without any records of sunspots or magnetic storms.

The following table is of interest in connection with the statement made earlier in this paper to the effect that those communications on great circle routes in the neighbourhood of the magnetic poles are more subject to fades lasting several hours than communications on other routes.

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TABLE 2.

Communication.	Number of fades observed October, 1927, to October, 1928.
Montreal to London	49
New York ,,	32
Cape Town ,,	4 (1 disturbed condition)
Java ,,	4
Poona ,,	7 (2 disturbed conditions)
Buenos Aires ,,	6

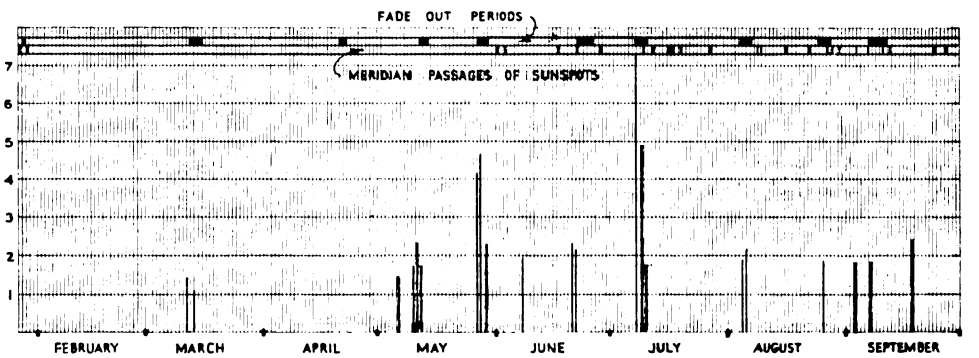

FIG. 9. *Observations taken at Chelmsford of Fade outs and Sunspots, 1928. Vertical lines proportional to Strength of Magnetic Disturbances.*

Application of Experimental Results.

The curves Figs. 10 to 15 have been obtained from an analysis of all the results obtained during the year's interception at Broomfield. They represent an average of the R strengths of signals received under different conditions of day, night and season, and corrections have been made in some cases in order that the curves may apply approximately to the case of a 10 kw. transmitter. Although the results are necessarily approximate due to the variability of short wave signals, and although the signal strengths only apply to a simple type of receiver and aerial as used during the year's interception at Chelmsford, the curves should give a better idea than hitherto possible of the results which may be expected on various long distance short wave communications. The curves are confined to distances beyond 1,000 km. and are applied in the following manner :

The light and dark grades on the shadow charts have been divided into six grades lettered A to D. The R strength of a signal traversing one grade only, may be obtained by subtracting from R9, the figure found in the ordinates of the curve

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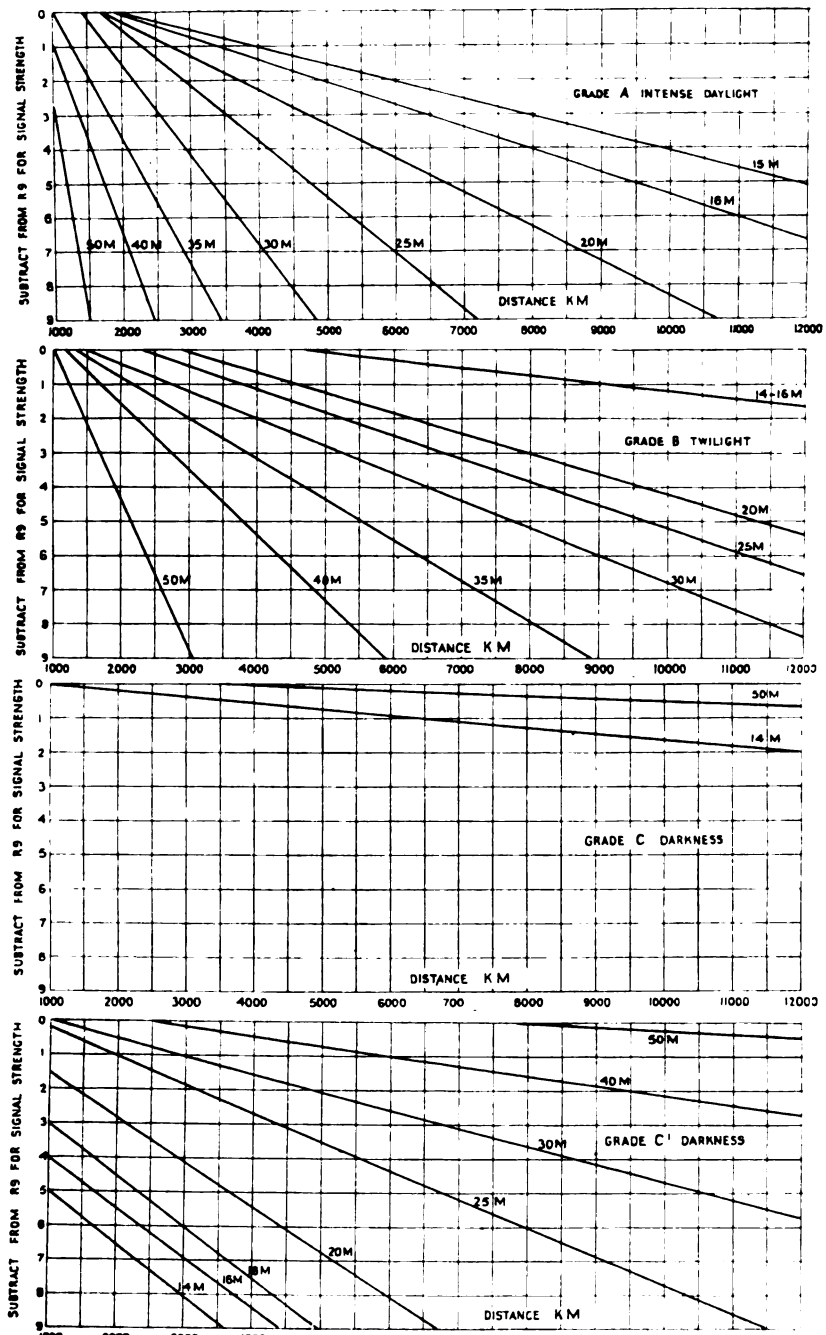

FIGS. 10, 11, 12 & 13. *Attenuation Curves.*

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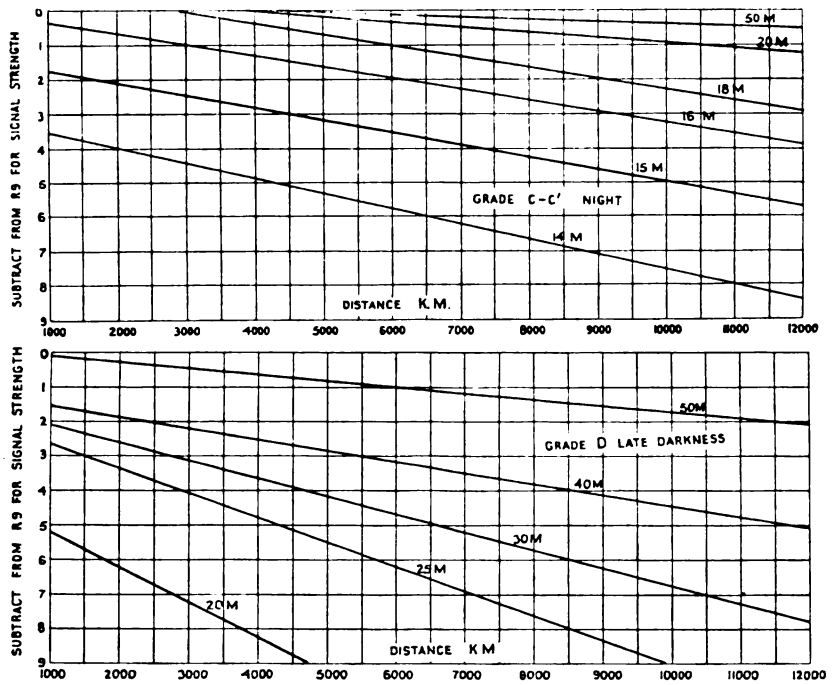
corresponding to the wavelength required, and the distance traversed in that grade. When two or more grades are included in the signal path, the sum of the ordinates for those grades is subtracted from R9 to give the final signal strength.



FIGS. 14 & 15. *Attenuation Curves.*

The following examples are given for the calculations of the signal strengths on some of the routes at midday during the winter.

	Figure to be subtracted from R9.		Final R Strength
LONDON—SAN FRANCISCO, 15 METRES.			
2,500 km. of grade B	0		
3,700 km. of grade D	9	15·5	0
2,300 km. of grade C'	6·5		
LONDON—SAN FRANCISCO, 30 METRES.			
2,500 km. of Grade B	·8		
3,700 km. of Grade D	3·5	5·7	3·3
2,300 km. of Grade C'	1·4		

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LONDON—MONTREAL ON 16 METRES.

In this case it will be seen that Montreal at midday G.M.T. is just on the border line between Grades D and B. The change in strength will be rapid at this time, from nil at 1100 G.M.T. due to Grade D over Montreal, to R9 at 1300 when the route is 5,000 km. of Grade B only. The small portion of Grade C′ has not been considered in the above cases.

LONDON—MONTREAL, 30 METRES.			
At 1100 *G.M.T.*—			
3,300 km. of Grade B	2·5	3·9	5·1
1,700 km. of Grade D	1·4		
At 1300 *G.M.T.*—			
5,000 km. of Grade B	2·8		6·2
LONDON—RIO, 15 METRES.			
1,700 km. of Grade B	0	4	5·0
7,500 km. of Grade A	4		
LONDON—RIO, 30 METRES			
1,700 km. of Grade B	0	9	0
7,500 km. of Grade A	9		
LONDON—MELBOURNE, 26 METRES.			
4,100 km. of Grade B	1·4	2·8	6·2
12,000 km. of Grade C	1·4		

It has been realised for some time that any reduction of signal strength on an all dark route is due to lack of bending or in other words to the "skip effect." Although this effect is most apparent in the case of comparatively short distances, up to, say, 1,000 km., it is frequently present in the case of considerably greater distances when dealing with communications in those dark grades which are reached during the later hours of the night, especially during the winter night. As an example, the skip may extend to 1,000 km. on a wavelength of 25 metres during the early hours of the night denoted by grade C on the shadow charts, but may extend to about 3,000 km. when the route lies in grade C′, and to infinity or rather to the maximum distance possible in grade D when the latter grade is reached. Any calculation of signal strength such as has been attempted by means of the attenuation curves, Figs. 10 to 15, previously described in this paper would be greatly simplified as regards all dark communications if no signals remained after the skip condition was reached. Actually, however, a scattered signal frequently remains. The strength of this

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scattered residual signal depends on the qualities of the scattering sources available and to a certain extent on the wavelength in use. The scattered signals on the longer wavelengths of about 30 to 40 metres being stronger than those on shorter wavelengths, it is evident that although the attenuation curves (Figs. 0 to 0 in this paper) are true attenuation curves for the daylight grades, they cease to be such in the case

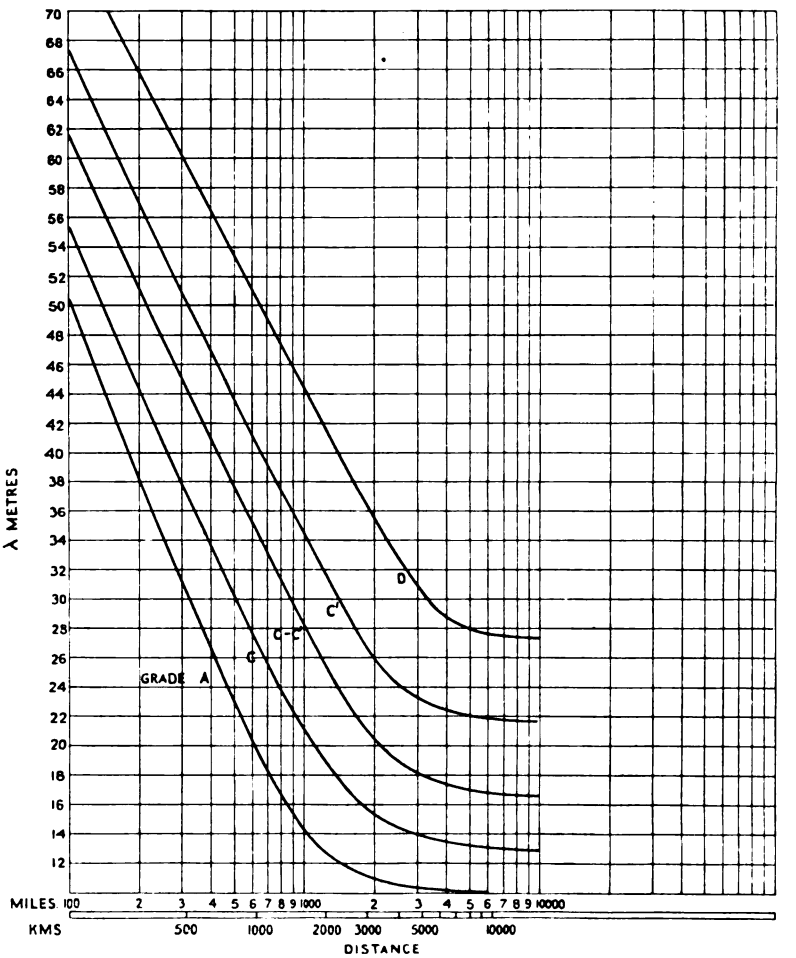

FIG. 16.

of the early night grades on the shorter wavelengths, and in the case of the later night grades on both the shorter waves and also the longer waves extending up to about 40 metres. It will be seen that the night attenuation curves obtained empiric-

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ally frequently deal with the strength of an entirely scattered signal in those cases in which the complete skip condition has been reached. The best indication of this condition is given by the direction finder and it is made immediately apparent by the absence of a true bearing, the latter being replaced by the bearing of the scattering source. As an example, signals from New York are frequently partially or entirely scattered from the south west at times at which the true great circle route passes through the winter night grades, and similarly signals from the far east with great circle routes through these winter dark grades are frequently partially or entirely scattered back from the lighter grades to the south east. If it is assumed that any scattered signal remaining after the skip condition has been reached is of very little value for commercial work, the prediction of good and bad times for various wavelengths under the various conditions is simplified considerably, and with this idea, a set of curves is now given, Fig 16, showing from our observations, the normal skip distances for various wavelengths for various distances where the routes lie entirely in the various grades A, C, C—C', C' and D. These grades with the corresponding letters have already been given in the shadow charts, Figs. o to o.

Where the route lies half in one grade, say grade D, and half in grade C', an interpolation may be made between the two curves for these grades. Any point for a given distance and wavelength will represent a skip condition for that wavelength when the point on the chart, Fig. 16, lies to the left of the curve for the trade under consideration.

As an example, at 1,000 miles, 30 metres will be inside the skip in grade C', but at 2,000 miles 30 metres will be outside the skip in the same grade. These curves representing the border of the skip cannot be taken as fixed, and are liable to variation from day to day with conditions, but they give an average obtained from a large number of observations over a long period. As regards the daylight skip distances for grade A, it should be mentioned that we have had no chance of studying these conditions for intertropical communications, and from some data obtained from Singapore it would appear that the daytime skip for any given wave may be less than in these latitudes.

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A VECTOR SOLUTION OF SHORT WAVE FEEDER PROBLEMS

Short wave aerials are usually situated several wavelengths away from the transmitting station to ensure correct radiation, and the power is supplied to the aerial through what is termed a "feeder." This usually consists of two concentric tubes, with the outer kept at earth potential, or two parallel wires, both insulated from earth.

The conditions obtaining in such a feeder cannot be determined by ordinary A.C. theory as applied to circuits containing only concentrated inductance and capacity. In a feeder the electrical energy travels in the form of electro-magnetic waves with equal and opposite currents in the two conductors at any particular section. If the dielectric between the feeder conductors is air, the velocity of such waves is almost equal to that in free space, and in the region of short waves is independent of the frequency.

THE following theory applies to one particular frequency only, and the simplest case to consider is that of a feeder of infinite length with an input EMF of E sin wt as shown in Fig. 1 (A). A and B represent the two conductors of the feeder, the arrow lines represent the electric stress between the conductors, and the + and − signs the electric charges on the conductors. The whole distribution shown travels down the feeder with a definite velocity, without change of form.

Let
- L = Inductance of feeder per cm length in henries.
- C = Capacity of feeder per cm length in farads.
- u = Velocity of waves in the feeder.
- i & v = Instantaneous values of current and voltage at any point.
- I_F & V_F = Maximum values of current and voltage.
- R_O = Surge impedance of feeder (to be defined later).

The charge on unit length of feeder at any point is Cv, and the instantaneous current is the charge multiplied by the wave velocity.

That is $i = C.v.u.$

and $$\frac{v}{i} = \frac{1}{C.u} = R_O = \text{constant for any particular feeder.}$$

It can also be shown that $R_O = \sqrt{\frac{L}{C}}$

A pure resistance R_O would require exactly these values of i and v. Therefore, if we cut an infinite feeder at any point and terminate it with a resistance R_O as shown in Fig. 2, the conditions in the remaining part of the feeder are unchanged. The waves travelling down the feeder are wholly absorbed in the resistance R_O. This is the condition usually aimed at in short wave working, as it gives the maxi-

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mum efficiency of transmission, the terminal circuit being adjusted to provide an effective load equal to R_0 at the frequency in use.

Since $v = R_0 i$

$V_F = R_0 I_F$ and V_F and I_F are in phase.

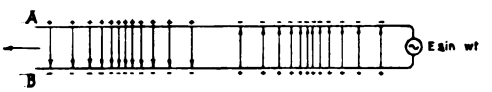

FIG. 1A.

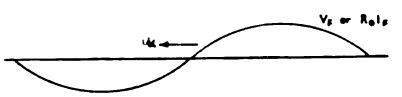

FIG. 1B.

In the general case there may be any number of waves travelling up and down a feeder independently, each with velocity u and for each of them the above relations hold. The resultant disturbance at any point is simply the sum of the disturbances due to the individual waves. The maximum value of current at all points of the feeder will be the same though it will not be reached at the same instant. Three ammeters are usually connected in the feeder at suitable spacing to indicate by their equal reading when the terminal load is correct.

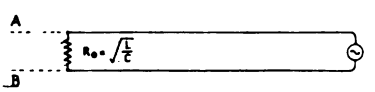

FIG. 2.

For any other value of load on a feeder the energy in the incident wave is partly absorbed and the remainder reflected to form a wave travelling in the opposite direction with the same velocity u. This travels back to the input end and is there reflected, and returns to the output end and so on. In the final state there is an infinite series of forward waves and an infinite series of reflected waves; but since all the waves have the same velocity, and the same ratio of current and voltage, we can treat the two series of waves as a single resultant incident wave giving rise to a single resultant reflected wave, and a resultant current in the load, which can be determined by the method given later. Then the whole disturbance at any point of the feeder is the sum of these two resultant waves.

Another way of regarding the problem is this. Let the input terminals be at infinity. Then we can have an infinite train of sinusoidal waves advancing down the feeder supplying current to the output circuit and being partially reflected. Then once the reflected wave is passing a point in the feeder, the steady state will be established at all points between that point and the output terminals. There will be a definite relation between I and V at that point, as regards amplitude and phase, and if we cut the feeder there, and provide these values of I and V from any combination of reactance and resistance, with the necessary internal E.M.F. this steady state will be maintained.

If $\frac{V}{I} = R_X + jX_X = Z_X$, Z_X may be called the equivalent impedance of the

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load and feeder at this point. *From this we see that the relative values of* I *and* V *and their phase relation at any point are determined entirely by the nature of the load and the surge impedance of the feeder and not at all by the input end. The absolute values of* I *and* V *however, are determined by the E.M.F. at the input end, and the equivalent impedance of the load and feeder at the transmitter.*

Let R = Resistance of terminal load.
X = Reactance ,, ,, ,,
R_O = Surge impedance of feeder.
V & I = the amplitudes of voltage and current in the load.
V_X & I_X = the resultant voltage and current at any point.
R_X & X_X = the effective series resistance and reactance at any point.
V_F & I_F = amplitudes of voltage and current in the forward wave.
V_R & I_R = ditto for reflected wave.

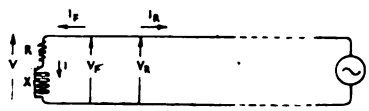

FIG. 3A.

Then with positive directions as shown in Fig. 3 (A).

$$\frac{V_F}{I_F} = \frac{V_R}{I_R} = R_O$$

also V_F & I_F are in phase
and V_R & I_R are in phase.

V = vector sum of V_F & V_R at the load $= \overline{V_F} + \overline{V_R}$

I = ,, difference of I_F & I_R at the load $= \overline{I_F} - \overline{I_R}$

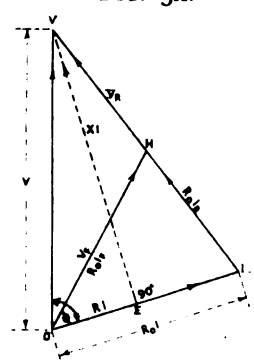

FIG. 3B.

In Fig. 3 (B) O H represents $\overline{V_F}$ at the load.
H V ,, $\overline{V_R}$ at the load.
so that O V ,, V.

For the triangle of currents we know

$$V_F = R_O I_F$$

and is in phase with I_F so that O H represents I_F multiplied by R_O.

Similarly if V H is produced to I making H I = V H = $V_R = R_O I_R$

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Then $O\,I = O\,H - H\,I = R_O(\bar{I}_F - \bar{\bar{I}}_R) = R_O\,I$

i.e., O I represents R_O I in magnitude, and angle V O I = ϕ the angle of lag of I behind V.

If we are given the value of R & X at the load to construct this Fig. 3 (B), assume a value for I. Then draw O E = R I and E V = X I. Then O V represents V and angle V O E = angle of lag of I behind V. Mark off O I along O E = R_O I. Join V to I and O to H the mid-point of V I. Then as before stated we have

O V	represents	V
O I	,,	$R_O I$
O H	,,	V_F and $R_O I_F$.
H V	,,	V_R
I H	,,	$R_O I_R$

This figure fully determines the conditions existing at the load.

To determine the conditions existing at a point in the feeder at a distance "x" from the load, we know the values of V_F and I_F existing at this point "x" will exist at the load $\frac{x}{\lambda}$ periods later (λ being the wave length in the feeder). Hence, if we rotate O H in a counter-clockwise direction about H through an angle $\frac{2\,\Pi\,x}{\lambda}$ radians (*i.e.*, $\frac{360\,x}{\lambda}$ degrees) we get V_F and I_F for the point x.

Similarly, for V_R and I_R the conditions at x are those existing at the load $\frac{x}{\lambda}$ periods before; so that we must rotate V H I in a clockwise direction about H through $\frac{2\,\Pi\,x}{\lambda}$ radians.

If we only require the relations of V_X and I_X we can leave O H fixed and rotate V H I in a clockwise direction through $\frac{4\,\Pi\,x}{\lambda}$ radians. V H I will then make a complete revolution for every $\frac{\lambda}{2}$ of the cable.

The resultant V_X and I_X for this point are given by O V and O I as before. Up to the present we have assumed that the transmitter is so far away that only a single incident wave, and a single reflected wave exist at the points considered. But as before mentioned, we can imagine the feeder cut at x and the transmitter connected there, and if this supplies the same values of V_X and I_X that already existed there, the same state of things will be maintained. The feeder and load will there-

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fore behave as an impedance $= \frac{\overline{V}}{I}$ as regards the transmitter. This may be termed the equivalent impedance of the feeder and load at the point "x" and will obviously vary with the distance x.

We can also imagine the feeder cut at "x," and the feeder beyond this point, and the load, replaced by the equivalent impedance, and the original state of things would persist in the remaining portion of the feeder.

An example is worked out in Fig. 4 for an inductive load in which $R=X=R_0$, but the remarks below apply to any inductive load.

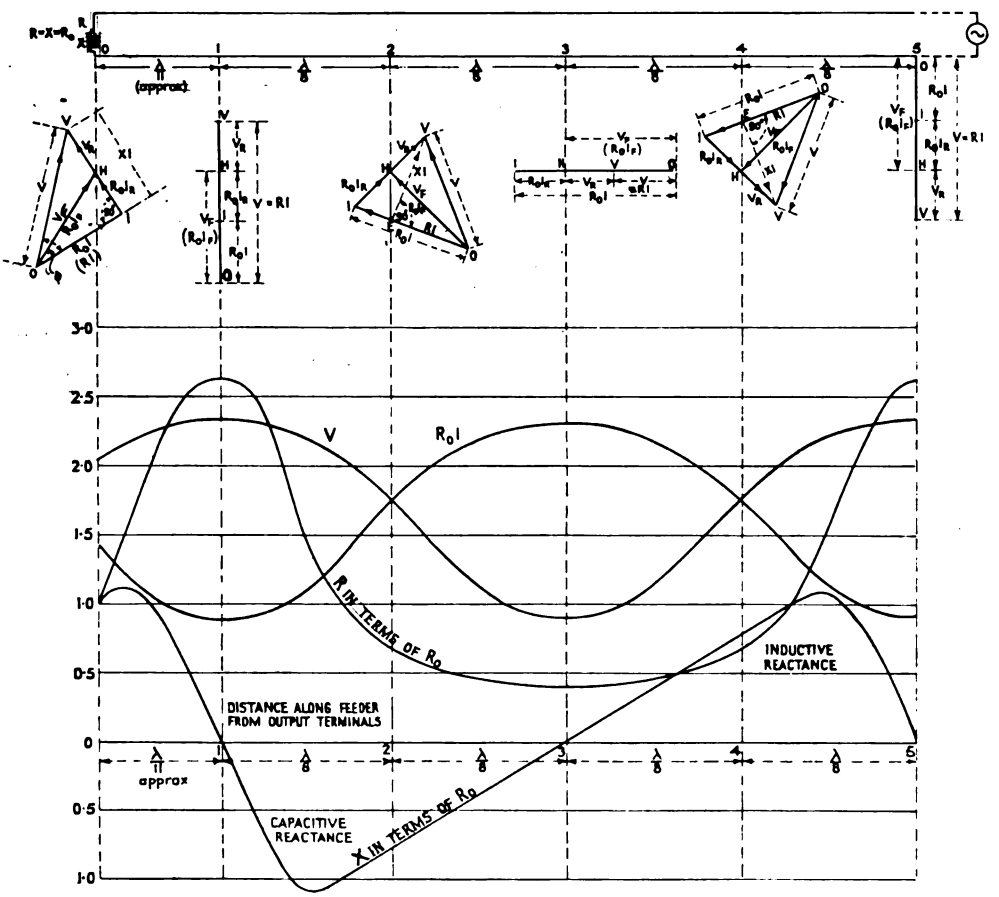

FIG. 4 (A) & (B).

At a distance less than $\frac{\lambda}{4}$ from the load O H and V H I come into line as shown

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in (A) 1. V and I are in phase, V (*i.e.*, O V) having its maximum value and I (*i.e.*, O I) its minimum value. Hence the equivalent impedance is a maximum, and is a pure resistance. At the point 2, $\frac{\lambda}{8}$ further from the load O H is at right angles to V H I and ϕ reaches its maximum negative value. O I = O V, *i.e.*, $V = R_0 I$. The equivalent impedance is equal to $\frac{V}{I} = R_0$ in magnitude but is capacitive.

$\frac{\lambda}{8}$ further back at 3, O H and V H I are in line again, but now V has its minimum value, and I its maximum value. Hence the equivalent impedance is a minimum, and is a pure resistance. If R_1 and R_3 are the values at 1 and 3 then $\sqrt{R_1 R_3} = R_0$.

$\frac{\lambda}{8}$ further back at the point 4, O H and V H I are at right angles again, the equivalent impedance is equal to R_0 but this time it is inductive. At the point 5, $\frac{\lambda}{8}$ further back still we get figure 5 which is similar to 1 except that all phases are reversed. Beyond this point the sequence will be repeated.

The curves of 4 (B) show how the resultant voltage and current vary from point to point on the feeder. It will be seen from these that three ammeters spaced about $\frac{1}{8}\lambda$ or $\frac{3}{8}\lambda$ apart will always give unequal readings while any reflected wave exists. Ammeters spaced $\frac{1}{4}\lambda$ apart might give equal readings even with strong reflected waves if they were situated at points such as 2 and 4.

In Fig. 4 (B) are also shown the variation in equivalent series resistance and reactance of the feeder and its terminal load. These are determined by drawing V E perpendicular to O I when $O E = R_X I$, and $E V = X_X I$ or

$$\frac{O E}{O I} = \frac{R_X I}{R_0 I} = \frac{R_X}{R_0} \text{ and } \frac{E V}{O I} = \frac{X_X}{R_0}$$

The case for any other load can be similarly worked out, but the general sequence can be deduced from the present set of curves. Thus, if the load is capacitive, it is equivalent to having the load situated in the section 1—3.

Pure Resistance Load.

If the load is a pure resistance it must be situated at 1 or 3, according as it is greater or less than R_0. If it is equal to nR_0, then at points along the feeder whose distances from the load are $\frac{1}{2}\lambda$, 1λ, $1\frac{1}{2}\lambda$, etc., the equivalent impedance is a pure resistance nR_0; whilst at points whose distances from the load are $\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$, $1\frac{1}{4}\lambda$, etc., it is a pure resistance $= \frac{1}{n} R_0$.

E. GREEN.

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PRACTICAL DETERMINATION OF THE TERMINAL IMPEDANCE OF SHORT WAVE FEEDERS

In the previous article a vector diagram was developed showing how the voltage and current at a given point in a feeder are related to the voltage and current at any other point.

It is the purpose of this article to show that this diagram may be completely determined in a practical case from the three current readings, normally taken on a standard feeder system, and that the fine adjustment to be made at the last feeder junction to reduce reflection to the practical minimum may be found in this way.

THE proposition which is used in the following pages is as follows :—

If OV and OI (Fig. 1) represent respectively the voltage at a given point A, and the product of the current at that point and R_o (the surge impedance of the feeder) the conditions at any other point at a distance x from A may be found by rotating the line VI about its centre H through an angle. $\frac{4\pi x}{\lambda}$ radii to a new position V^1I^1. The vectors OV^1 and OI^1 will represent current and voltage at the new position. (N.B.—direction of rotation anticlockwise when moving towards the output end)

DATA REQUIRED. Three ammeter readings I_a, I_b and I_c. Distances between ammeters d_1 and d_2. Distance from last ammeter to termination (d_3).

TO FIND the relation in terms of R_o between voltage and current at the terminating impedance.

CONSTRUCTION (Fig. 2). Draw a circle of convenient radius. Draw radii HA, HB and HC, so that

$$\widehat{AHB} = \frac{4\pi d_1}{\lambda}$$

$$\widehat{BHC} = \frac{4\pi d_2}{\lambda}$$

Along A B mark off BD so that

$$\frac{BD}{DA} = \frac{I_b}{I_a}$$

Along AB produced mark off BK so that

$$\frac{BK}{KA} = \frac{I_b}{I_a}$$

With centre E and KD as diameter describe a circle.

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Similarly along CB make

$$\frac{BF}{FC} = \frac{I_b}{I_c}$$

and along CB produced make

$$\frac{BL}{LC} = \frac{I_b}{I_c}$$

and with centre G describe a circle having FL as diameter. Let these two circles intersect at O, then OA : OB : OC = I_a : I_b : I_c.

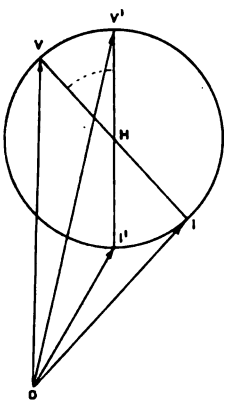

FIG. 1.

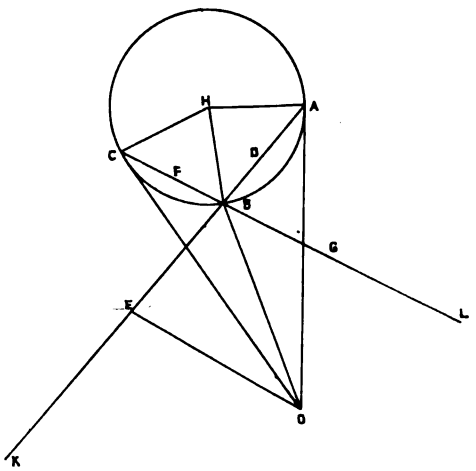

FIG. 2.

PROOF.

Let BD = b and AD = a

Then $\frac{BD}{AD} = \frac{b}{a}$ $\frac{BK}{AK} = \frac{b}{a}$

And AK = BK + BA = BK + $(a + b)$

Whence $BK = \frac{b(a+b)}{a-b}$ $DK = \frac{b(a+b)}{a-b} + b = \frac{2ab}{(a-b)}$

$ED = \frac{ab}{(a-b)} = EO.$

And $EB = ED - HD = \frac{ab}{(a-b)} - b = \frac{b^2}{(a-b)}$

And $BA = ED + DA. = \frac{ab}{(a-b)} + a = \frac{a^2}{a-b.}$

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Now $$OB^2 = EO^2 + EB^2 - 2EOEB \cos \widehat{OEB}$$

$$= \frac{a^2 b^2 + b^4 - 2ab^3 \cos \widehat{OEB}}{(a-b)^2}$$

$$= b^2 \left\{ \frac{a^2 + b^2 - 2ab \cos \widehat{OEB}}{(a-b)^2} \right\}$$

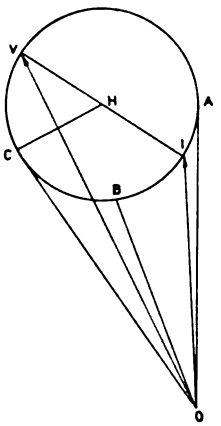

FIG. 3.

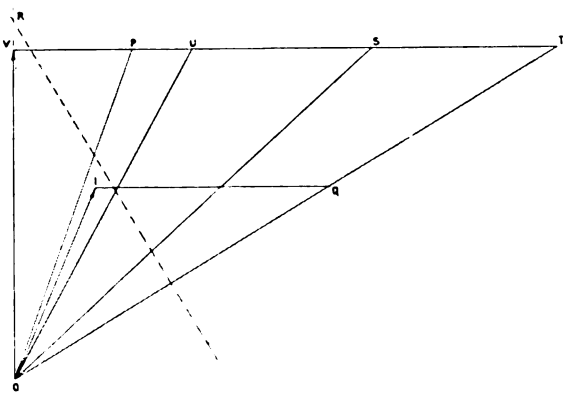

FIG. 4.

And $$OA^2 = EO^2 + EA^2 - 2EOEA \cos \widehat{OEA}$$

$$= \frac{a^2 b^2 + a^4 - 2a^3 b \cos \widehat{OEA}}{(a-b)^2}$$

$$= a^2 \left\{ \frac{a^2 + b^2 - 2ab \cos \widehat{OEA}}{(a-b)^2} \right\}$$

Whence $$\frac{OB^2}{OA^2} = \frac{b^2}{a^2} \qquad \frac{OB}{OA} = \frac{b}{a} = \frac{BD}{AB} = \frac{I_b}{I_a}$$

Similarly $$\frac{OB}{OC} = \frac{I_b}{I_c} \qquad OA : OB : OC = I_a : I_b : I_c.$$

Now from H draw HI, so that

$$\widehat{CHI} = \frac{4\pi d}{\lambda}$$

Draw the diameter IHV.

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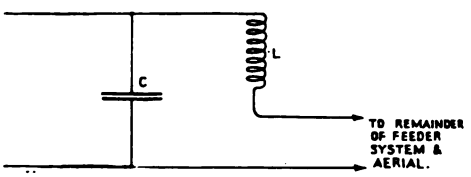

FIG. 5.

Then OV and OI will represent the voltage and current vectors at the last junction and completely define (in terms of R_o) the impedance of the feeder and aerial system from that point onward.

To FIND the necessary adjustment at the last junction.

For ideal termination OI must coincide with OV. The necessary changes to the inductance (L) and the capacity (C) may be determined as follows.

DATA REQUIRED. Length "l" of each condenser tube

CONSTRUCTION (Fig 4) From V draw a line at right angles to OV and make $\widehat{VOP} = \frac{2\pi l}{\lambda}$

From I draw IQ at right angles to OV, making IQ = 2VP.

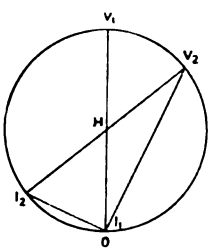

FIG. 6.

Then $OQ = R_o \times I_l$ where I_l is the current through inductance L and the remainder of the feeder system (Fig. 5).

PROOF.—Each condenser tube is a length of feeder of surge impedance R_o terminated by an infinite impedance (open circuit). The vector diagram is as in Fig. 5. The current through the terminating impedance being zero I_1 coincides with O. To find the conditions at a distance "l" from the open end rotate V_1 I_1 clockwise about its centre through an angle $\frac{4\pi l}{\lambda}$ obtaining the new positions V_2 and I_2.

Since $HV_2 = HI_1$

$$I_2\widehat{V_2O} = H\widehat{O}V_2 = \tfrac{1}{2} I_2\widehat{H}I_1 = \frac{2\pi l}{\lambda}$$

VP in Fig. 4 represents in length the product of R_o and the current to one condenser tube. IQ represents the product of R_o and the current to both tubes, *i.e.*, $R_o \times I_c$ but is drawn in the negative direction.

Now vectorially $OQ = OI + IQ = I \times R_o - I_c \times R_o = I_l \times R_o$

Now Bisect OQ at right angles and let the bisector cut OV at R. With centre R describe an arc from Q cutting VP produced at S. Variation of the value of L will make Q move along the arc towards S and to make Q coincide with S the inductance must be varied in the ratio VS/VT (T being the intersection of OQ and VS produced).

Since $VS/VT = \dfrac{\tan VOS}{\tan VOT} = \dfrac{I_1/R}{I_2/R} = I_1/I_2$

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(where L_1 = value of inductance as set
L_2 = ,, ,, ,, required
R = impedance of remainder of feeder system.

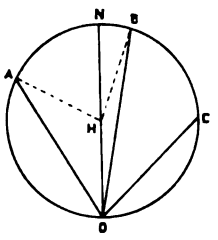

FIG. 7.

Now Bisect VS at U.

If l is altered so that

$$\widehat{VOU} = \frac{2\pi l}{\lambda}$$ then the current I_c will be equal to SV and I will then coincide with V.

SUMMARY. To effect correct termination change L in the ratio VS/VT.

Change "l" in the ratio $\widehat{VOU}/\widehat{VOP}$.

Note.

This construction can give very satisfactory results in practice but it has its limitations. For instance the positions of the points G and E are fundamentally important but depend on the accurate determination of a small difference between two comparatively large observed values. It is therefore necessary to make careful calibration of the feeder ammeters at the frequency of measurement. For more accurate work a fourth meter might be introduced to check observational error. This would give—for the point O the intersection of three arcs instead of two and hence three alternative positions from which could be taken—as a fair mean—the centre of the circle passing through the three of them. In addition no account is taken in the original proposition of the effects of the small losses in the feeder due to resistance and leakance. Since however the impedance of a pair of aerials varies to some extent with temperature and windage, and the effect on reflection of expansion and angle boxes in the feeder must be appreciable, a complete and permanent elimination of reflection cannot be obtained.

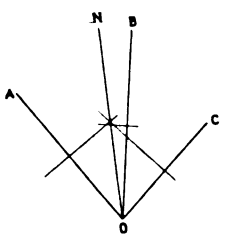

FIG. 8.

Another point that has been taken for granted in Fig. 4, is that the load represented by the remainder of the feeder is for all practical purposes a resistance. For the normal two-to-one junction this should be equal to $\frac{1}{2}$ R_o and its approximation to this value is indicated by the margin by which point R (Fig. 4) fails to coincide with V. Actually this load will rarely be purely resistive but will be equivalent to a resistance in series with a small reactance (capacitative or inductive). So long as this is reasonably small with regard to $L\omega$ no serious error will be involved by neglecting it Even should it be large the error does not occur until the computation of the required value of L for the proper termination. Any small reactance in series with the load is also in series with that load and hence

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$$\text{instead of } VS/VT = \frac{L_1}{L_2}$$

$$\text{the equation becomes } VS/VT = \frac{L_1\omega + X}{L_2\omega + X}$$

Where X is this unknown reactance (if it were considerable its actual value could be determined from a separate set of ammeter readings).

There is however one factor which can seriously upset calculations and that is the actual wavelength along the feeder. As this will be slightly different from the wavelength of radiation a definite measurement should be made on the feeder itself. This can conveniently be done by open-circuiting the feeder at the distant end and taking three ammeter readings as before, calculating the wavelength from a construction based on Fig. 6, where on account of the fact that the feeder is open-circuited O will be on the circle generated by the rotation of VI.

Hence if OA, OB and OC (Fig. 7) are three ammeter readings, all four points O, A, B and C will be on a circle and

$$\overset{\frown}{AOB} = \frac{2\pi d_1}{\lambda}$$

$$\overset{\frown}{BOC} = \frac{2\pi d_2}{\lambda}$$

$$\left(\text{Because } \overset{\frown}{AOB} = 1/2\ \overset{\frown}{AHB} \text{ and } \overset{\frown}{AHB} = \frac{4\pi d_1}{\lambda}\right)$$

Select then an arbitrary value for λ and draw OA, OB and OC at the angles corresponding to this value. Draw the perpendicular bisector of OA and find the position of M the intersection of the perpendicular bisectors of OB and OC.

Let OA remain fixed and repeat for successive values of λ (thus obtaining the locus of the point M). Continue until this locus cuts the perpendicular bisector of AO. This will give a value for λ but on account of observational error in meter readings the accuracy of the result may not be better than 2 per cent. A more exact value is given by calculating for a close succession of values of λ the angular distance from A of the nearest antinode of current working backwards from the node which necessarily exists at the far end. This antinode should appear on the diagram as a diameter and hence should pass through H. If the distance from A is many wavelengths this line (ON Fig. 7) will move exceedingly rapidly with the value of λ in comparison with the movement of say OB or OC. With very little difficulty a value for λ may be found such that ON passes through the centre of the small triangle formed by the three bisectors of OA, OB and OC (Fig. 8). If ammeter readings are taken with care this triangle will be reasonably small and an accuracy of 1/10th of 1 per cent. may be expected in the resultant value of λ. Experiments on 24 and 28 metres give a value of λ in the feeder equal to 97·64 per cent. of its value in space.

L. T. BIRD.

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MARCONI NEWS AND NOTES

INTERNATIONAL NAVAL CONFERENCE IN LONDON

His Excellency Mr. Reijiro Wakatsuki (fifth from the left), Japanese Envoy to the International Naval Conference, and party, at the Marconi Beam Station at Dorchester.

Speeches Broadcast Throughout the World.

The speeches of the King of England and the principal national delegates at the opening of the London Naval Conference on January 21st were broadcast through the agency of the British Broadcasting Corporation, and heard by wireless listeners practically throughout the civilised world. A new record in simultaneous world broadcasting was established, and in this feat the Marconi Company played a prominent part in several ways.

Long wave and short wave omnidirectional stations and the Marconi short wave Beam stations at Dorchester and Bodmin were used in Britain to broadcast the speeches to all parts of the world for relaying from more than 200 oversea stations.

The high power long wave station at Daventry, 5XX, supplied by the Marconi Company to the British Broadcasting Corporation, was picked up by many Continental Stations. Further afield, the programme transmitted by the experimental short wave broadcasting station 5SW at the Marconi Works, Chelmsford, was well received and re-broadcast. Of this station, the *Wireless World*, the well-known

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British wireless journal, stated :—

> " The honours go to 5SW. Several stations on the Continent which had arranged to take the broadcast by land line, chose the less expensive but equally efficient method of tuning in Chelmsford. Among the stations which preferred this method were Turin, Naples, Stockholm and Vienna, the last two starting with landline, but resorting to 5SW because the transmission was better."

Listeners in more distant countries also heard the broadcast direct from 5SW. Apart from the Naval Conference broadcast the Marconi Company is constantly receiving excellent reception reports of this station from short wave listeners as far afield as South Africa, India and Australia.

Beam Broadcasting Link.

As in the case of previous international broadcasts from Great Britain—such as the broadcast of the Thanksgiving Service at Westminster Abbey for the King's recovery in July last—Canadian listeners were well served by the Marconi Beam station at Bodmin, which provided a highly efficient transatlantic " link." The signals were strongly received by the Canadian Marconi Company's Beam receiving station at Yamachiche, and very successfully re-broadcast throughout the Dominion by a chain of 25 stations.

The programme was also received by Beam in Australia, the Canadian Marconi Company relaying the signals received by transatlantic Beam over the Montreal-Melbourne Beam circuit.

The Japanese Envoy at the Microphone.

Britain - Japan Beam Telephony.

At a later stage during the Naval Conference, the Marconi Beam system was again brought into use to enable His Excellency, Mr. Reijiro Wakatsuki, the Japanese Envoy, to speak by wireless telephone from Britain to Japan.

The Marconi wireless telephone installation was connected to the Beam telegraph aerial used for telegraphy with Japan, and reports received indicate that Mr. Wakatsuki's voice was heard as clearly in Japan as it was in the little room at Dorchester. Not only was it heard at the Beam receiving station at Yokkaichi, but it was broadcast to the whole Japanese nation through the Japanese Broadcasting

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Association's chain of stations covering Japan from Sendai in the North, Tokyo, Osaka, Nagoya, and Hiroshima, to Kumamoto in the South.

As Mr. Wakatsuki was speaking the members of his staff who were with him received reports by wireless telegraph every minute stating that his voice was being heard perfectly with every word clear and distinct. At the conclusion of Mr. Wakatsuki's speech, one of the party went to the telephone and said: "Hello, Japan. We are glad that you have had the opportunity of hearing Mr. Wakatsuki's speech. How did you hear him?"

Back came the immediate reply by wireless telegraph—no Beam telephone transmitter being yet available in Japan: "Perfectly. We are very gratified that, thanks to the wonderful achievement of the Beam wireless system of telephony we have been able to hear our envoy himself speaking to us."

Mr. Wakatsuki was equally pleased at the opportunity that had been given him, and in the course of his speech, said: "I rejoice that the completion of the Beam system by the Marconi Company has now made possible the direct transmission of speech between England and Japan, separated by 10,000 miles of sea and land, and I am very happy to avail myself of this wonderful invention to address my fellow countrymen at home while I am in London on this important mission. A wonderful invention by scientists such as this, which can carry the human voice from London to Tokio, should inspire us all to redouble our efforts to overcome any obstacles that hinder the world's progress to peace."

Beam Transmitting and Receiving Aerials.

Mr. Wakatsuki spoke into an ordinary Post Office telephone as he would have done in telephoning from his home to a friend. The telephone was connected to the modulating panel of a Marconi short-wave Beam transmitter connected to the aerials by means of which the Beam signals are directed towards Japan. A programme of gramophone records, including songs in Japanese and orchestral pieces, was transmitted for re-broadcasting at the close of Mr. Wakatsuki's address.

In Japan the signals were received on the Beam receiving aerial at Yokkaichi station and transferred to the landlines connecting up all the Japanese stations from which the speech was broadcast.

There are seven transmitters at the Dorchester Beam station, and if there were suitable receivers in the Argentine, Brazil, United States of America, Egypt, Siam, or any of the other countries with which Dorchester carries out Beam telegraph services, wireless telephone conversations could be carried out with any and all of them through this station without interfering with the telegraph services. The Dorchester station in fact, might be regarded as a wireless telephone switchboard, through which it would be possible, with suitable equipment, to speak to all four corners of the world either at one time or to one country after another as quickly as one could be switched through from Rio de Janeiro to New York and from New York to Cairo and Tokyo.

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THE MARCONI REVIEW

March, 1930

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THE MARCONI REVIEW

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General Editor: W. G. RICHARDS.

THE MARCONI RADIO TELEPHONE TERMINAL EQUIPMENT

The following article describes in detail the apparatus required to enable two way communication to be carried on over a combined Radio and Land Line link under commercial conditions.

The necessity for the change from a normal 2-wire to a 4-wire Land Line system is explained, and the use of echo suppressors is discussed. In conclusion, the means provided for checking and controlling the various parts of the apparatus are described.

IT is common knowledge that in the usual local telephone services a subscriber communicates with another by means of a pair of wires used to convey speech in both directions. In this case the communication is said to be on 2 wires.

On radio telephone services, on the contrary, where the radio transmitting station and the radio receiving station are usually situated a few miles apart, it is necessary to make use of a 2-wire line to carry the speech to the radio transmitting station, and of another 2-wire line to carry the receiving current from the radio receiving station to the auditor. In this case the communication is said to be on 4 wires.

To link an ordinary 2-wire subscriber telephone network to a radio channel, or *vice versa*, it is then necessary to provide for a landline device to afford a means of passing from a 2-wire system to a 4-wire system or *vice versa*.

Such an arrangement—called a "hybrid" circuit, Fig. 5 is a kind of electrical bridge in which the four arms are respectively constituted on the one hand by the two pairs of lines of the 4-wire communication, and on the other hand by the two lines of the 2-wire communication system, and an equivalent network balancing as near as possible the characteristics of that line.

With this arrangement, and assuming ideal conditions, no receiving speech current from the 4-wire system can pass into the transmitting line of the 4-wire

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system. In practice, however, this state of perfection is never realised, and consequently a certain amount of receiving current always passes into the transmitting line, and reaches the speaker through his own radio receiving station.

As this imperfection of balance exists at both ends, a certain portion of the retransmitted energy is again super-imposed on the speech, thus returning to the subscriber as an echo. This state of affairs is unacceptable in commercial working, becauses it creates a serious kind of cross-talk which reduces intelligibility, and, in extreme cases, it can set the whole circuit in "singing" condition, and it has therefore been found necessary to introduce special apparatus known as "echo suppressors."

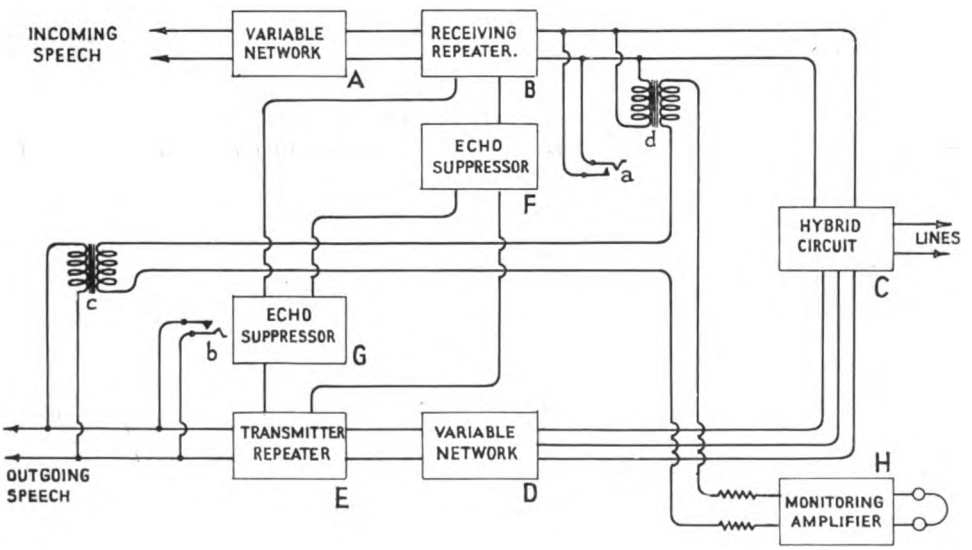

FIG. 1.

The volume of speech reaching the point where the 2-wire system links with the 4-wire radio circuit, in practice arrives with extreme variation of intensity, due to the length of the 2-wire subscriber line, the condition of the microphone, the natural strength of the voice of the speaker, and the way he is talking into or holding the microphone. Consequently, to obtain a normal modulation at the radio transmitter in each case, it is necessary to provide for a monitoring device, which, associated with measuring apparatus, permits the distant control of that modulation.

It is thus found convenient to have some means of calibrating the volume indicator as a function of its corresponding effect on the radio transmitter.

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The whole of the apparatus required efficiently to operate and handle the linking up of a 2-wire to a 4-wire system, involving a radio circuit, is called a telephone radio terminal equipment, and is illustrated, in diagrammatic form in Fig. 1.

FIG. 2.

As the losses of a unidirectional 2-wire system can always be reduced to a very small degree by means of suitably distributed amplifiers along the line, it is always an advantage to install the equipment as near as possible to the central office of the 2-wire subscriber network into which it has to work normally.

The Marconi radio telephone terminal equipment consists of a number of units supported in an iron frame. Fig. 2. The construction of these units is in every respect similar to that already adopted for the construction of the standard Marconi Beam receiver. This type of construction ensures an excellent electrical screening and an effective protection of all parts against dust, insects and moisture, and consequently will give satisfaction under the most severe climatic conditions.

Mechanical generators used in connection with suitable electrical filters dispense with the need of L.T. and H.T. batteries, but of course, they can be replaced by batteries if so desired. In this case a 120 volt H.T., one 8 volt L.T., and one 24 volt L.T. battery are used.

In the case of the generator battery eliminator equipment, the driven motor can be supplied to suit any mains supply available.

The equipment incorporates the following items :—

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Landline Amplifiers.

There are three 2 valve landline amplifiers. The maximum gain of these amplifiers is 40 decibels, and is adjustable by means of a calibrated resistance attenuating network, mounted in the input circuit of the amplifier.

This calibrating network is also used in connection with the valve voltmeter and the 1,000 cycle generator for measurement purposes as hereafter mentioned.

The input transformers are electrostatically screened.

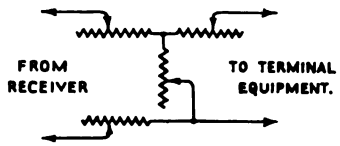

FIG. 3. A in FIG. 1.

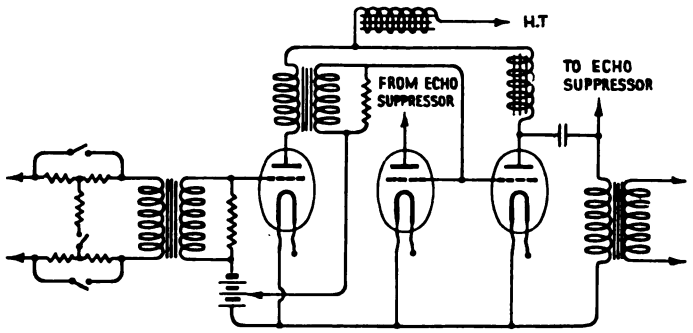

FIG. 4. B in FIG. 1.

The input and output impedance of these amplifiers is 600 ohms. The second stage of amplification of these amplifiers is fitted with a coupling valve whose output works into the echo suppressor units, thus preventing any reaction from the echo suppressors into the amplifier itself.

Normally one of these amplifiers is used as a one-way repeater inserted in the line going to the radio transmitter, Fig. 9, and the other in the line coming from the receiving station, Fig. 4.

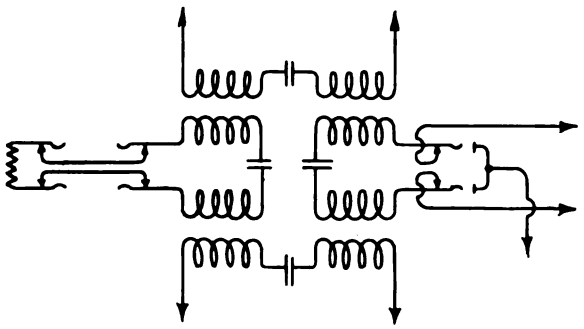

FIG. 5. C in FIG. 1.

The third is used either as a spare or as a monitoring amplifier, Fig. 11, or in conjunction with the valve voltmeter unit for the measurement of noise level.

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Chokes and condensers in the L.T. and H.T. supply prevent cross talking.

Jacks permit the measurement of the plate current and the correct adjustment of all the grid bias batteries.

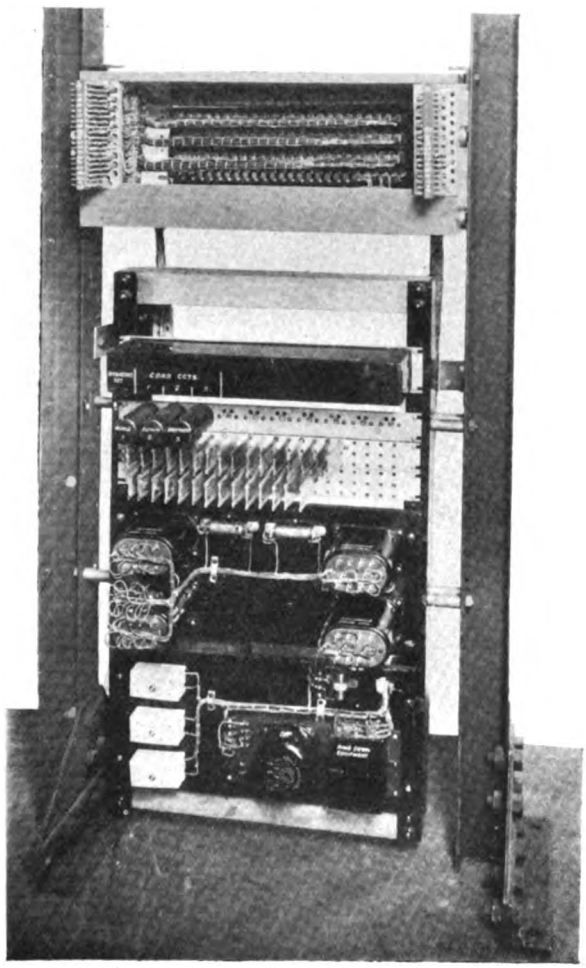

FIG. 6.

Echo Suppressors.

These are two in number named the receiving and transmitting echo suppressors respectively. With the method adopted by the Marconi Company, the transmitter echo suppressor closes the receiving line of the speaker while transmitting and the receiving echo suppressor of his listener closes the transmitting line of the latter.

As soon as the speaker ceases talking or pauses between words, both lines are automatically freed again.

This arrangement completely prevents any noise coming from the reception end from being superimposed on speech or the cutting of the speech by the echo suppressor, due to accidental coughing or shaking of the microphone by the auditor.

The echo suppressor apparatus, Fig. 10, consists of two stages of L.F. amplification in addition to the two-stage landline amplifier already described, and arranged so as to favour all frequencies around 1,000 cycles, thereby minimising inaccurate working due to noise level.

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The output of the last stage amplifying valve works into a diode rectifier followed by one stage of D.C. amplification. The output of the latter controls the mechanical relay which paralyses one of the landline amplifiers by short circuiting the primary of its inter-valve transformer. This operation has been rendered practically noiseless by preventing the D.C. component of the plate current of the first stage valve of the landline amplifier, from passing through that winding.

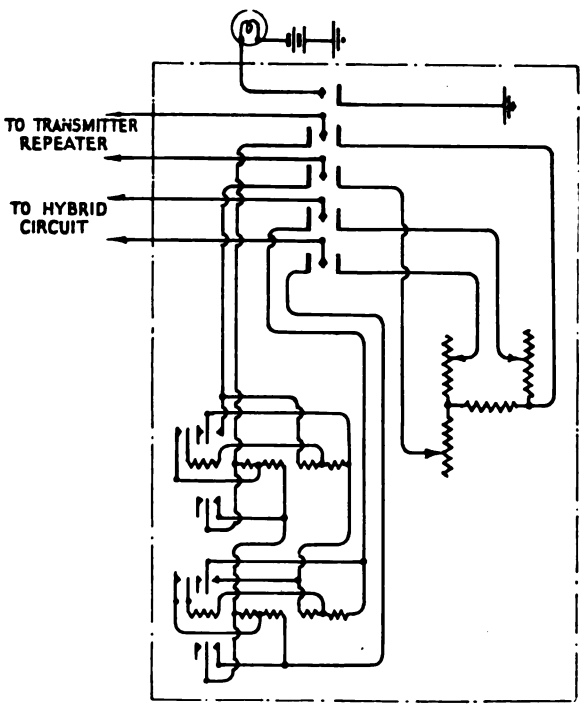

FIG. 7. D in FIG. 1.

This arrangement also has the advantage of not altering either the input or the output impedance of the amplifier.

The other contacts of this relay are used to control a lamp indicator showing the normal operation of the system.

The time of closing and the time of opening of that relay under the action of the speech is adjustable as well as the sensitiveness of the device taken as a whole.

The time adjustment of the operation of the device is obtained by :—

(i) Varying the biasing current flowing in the auxiliary winding of the relay.

(ii) Varying the time constant of the charge of condensers shunted by resistances which are mounted in the grid of the last amplifying valve.

Jacks and switches permit the checking and adjusting of the plate current of each valve.

The method used for the blocking of the transmitter echo suppressor by the receiving echo suppressor, is very important. This is effected by heavily biasing the grid of the first valve of the transmitting echo suppressor by means of the

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rectified current of the diode rectifier of the receiving echo suppressor. This action is instantaneous in comparison with that of the mechanical relay and prevents both echo suppressors from working simultaneously, which would immediately establish an uncommercial condition.

FIG. 8.

Bad balance at the hybrid coils aggravated by the necessity of using a large gain at the receiving landline repeater due to the weakness of incoming speech, might readily bring about this uncommercial condition, if it were not for the action of this special blocking device

The valve voltmeter unit in conjunction with the 1,000 cycles unit, is used to perform a series of measurements which will be indicated later.

The tone generator is designed to permit the calibration of the valve voltmeter, so that a given point of its scale indicates 1 milliwatt in a line of 600 or 900 ohms which unit is used as zero level in all the measurements.

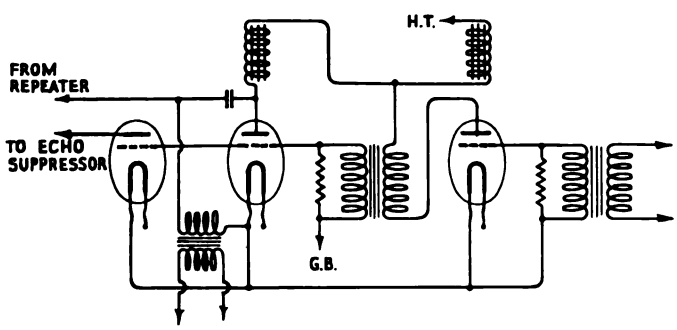

FIG. 9. E in FIG. 1

To avoid the absorption of energy by the use of the valve voltmeter, its input impedance has been made high in comparison with that of the line. The loss introduced by its use is below $\frac{1}{4}$ decibel.

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The tone generator is used for the lining up of the transmitter by adjusting the gain of the amplifier feeding the modulating panel of the transmitter itself, so that a given level output at the terminal equipment can be taken as a basis for its correct modulation.

This generator is also used for morse communication between the stations.

In view of facilitating the adjustment of the balance of the hybrid coil by limiting the range of frequencies in which the balance must be effectuated, low pass filters are used in the circuit leading to the receiving repeater and echo suppressor. Incidentally the time lag which it introduces into the circuit helps the working of the interlocking arrangement between the echo suppressors which we have just described.

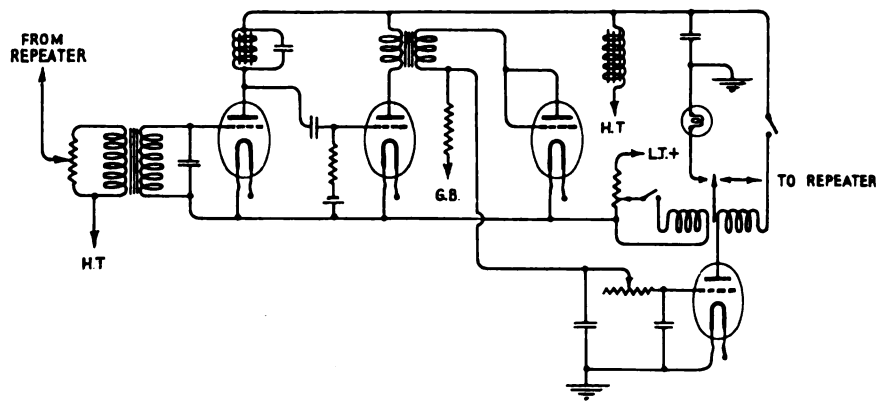

FIG. 10. F & G in FIG. 1.

The control unit consists of a switchboard on which are mounted milliammeters, voltmeters, fuses and switches. It also involves a valve characteristic test circuit and facilities for using the instruments for the adjustment of the grid bias of every valve.

The control table is a compact unit which contains a jackfield and the standard telephone apparatus of this special equipment, and is shown in Figs. 6 and 8. It normally provides for three complete standard trunk cords, each having the three positions of

(A) Speaking to radio,
(B) Speaking to landline,
(C) Speaking to both simultaneously, and

in addition, a monitoring position.

This number of call cords could be increased if desired.

Lamps are used as calling indicators, and a magneto circuit is used for land-line ringing.

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From the diagram it will be noted that all the monitoring coils, hybrid coils, landline amplifiers, echo suppressors, &c., have their inputs and outputs connected to jacks. This permits the testing of each piece of apparatus separately, their replacement by spares or their re-arrangement into any desired combination.

The control table also incorporates two adjustable monitoring attenuating networks, Figs. 3 and 7, introduced in the input circuit of the receiving and transmitting landline amplifiers, which, in conjunction with the valve voltmeter, provides a control of the monitoring circuit.

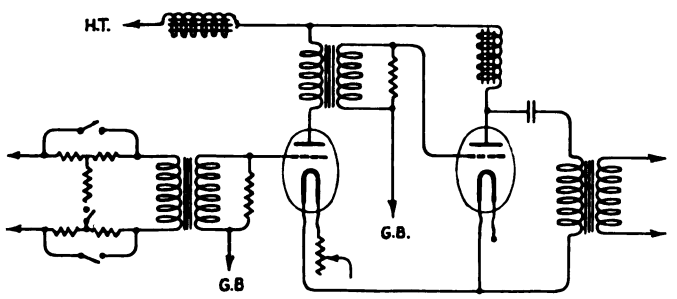

FIG. 11. H in FIG. 1.

The fact that the adjustment of the modulation for a given speaker will, in nearly every case, differ from the adjustment required for the operator speaking from the terminal equipment, and the necessity of being able to intervene in the case of misunderstanding or difficulty occurring during a call, complicates the operation, and would normally necessitate re-adjustment of the gain for which, in practice, there is no time. This is completely avoided by the use of an extra relay, which, by moving the splitting key through "monitoring" to "talking," automatically changes the gain of the amplifiers by the introduction of a suitable attenuating network.

Attenuating networks of 4 Db. are introduced in the input and output of the hybrid coils for the purpose of facilitating the balance.

The combination of the valve voltmeter unit, 1,000 cycles generator and the spare amplifier enables the following measurements to be made :—

(i) To measure the amplification of each amplifier.

(ii) To adjust the valve voltmeter to read zero level or 1 milliwatt output, or any desired plus or minus value between −50 to + 10 Db's.

(iii) The measurement of the balance in Db's.

(iv) The singing point of the amplifiers for a given balance and adjustment of the gain.

(v) The testing of the echo suppressors.

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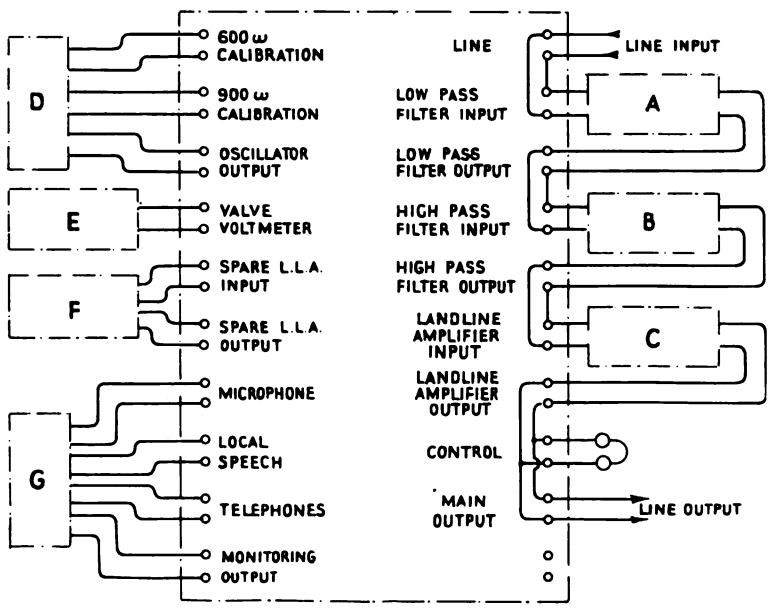
(vi) The measurements of the attenuation of any loop line in Db's.
(vii) The measurement of the noise level of the line alone, of amplifiers, or of the radio line under commercial working conditions.

The jack and switch facilities permit :—

(i) The linking up of a subscriber 2-wire circuit with the 4-wire radio circuit.
(ii) The speaking from the terminal on 4 wires or on 2 wires.
(iii) The extension from the terminal of the 4-wire system to another 4-wire long distance circuit.



A. Low pass filter. *E. Valve voltmeter.*
B. High pass filter. *F. Spare landline amplifier.*
C. Landline amplifier. *G. Landline unit.*
D. 1,000v oscillator.

FIG. 12.

A high impedance monitoring circuit used in connection with the monitoring amplifier, permits the possibility of listening to the conversation independently of the normal monitoring circuit, thus permitting a supervisor or chief of staff to listen from the terminal board or from a distance, for controlling purposes. (C, D & H, Fig. 1.)

Monitoring high impedance input transformers provide a possibility of listening directly and separately to the radio receiving and transmitting lines.

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In the case of very important commercial services, where interruptions of a few minutes cannot be permitted, it is possible to add to the normal equipment an additional lag to the rack, and duplicate the echo suppressors, the landline amplifier, which in case of trouble can be immediately introduced into the circuit in the place of the faulty or doubtful instrument in service. It is also possible to add a standard tone generator giving a constant output of all frequencies of from 10 to 10,000 cycles, for the purpose of equalising lines or measuring lines at any given frequency.

In addition to the radio terminal equipment, it is convenient, if not essential, to have a corresponding terminal equipment at the transmitting station itself.

In the case of a radio telephone service, this equipment can be reduced to one control unit, similar to the one described above ; one valve voltmeter with which the 1,000 cycles calibrating generator can be combined ; one landline amplifier ; a small jackfield unit and a landline box.

This equipment permits the exact lining up of the circuits, and also the checking from the transmitting station and the amount of modulation received from the central office at any time, A spare amplifier in the case of important services is advisable but is not essential.

Fig. 12 gives a schematic diagram of the complete equipment.

G. A. MATHIEU.

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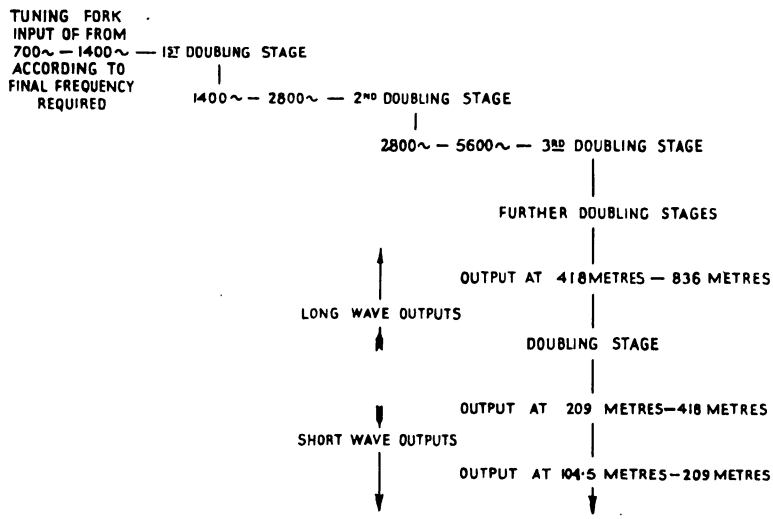
A CONSTANT FREQUENCY CONTROL FOR BROADCAST TRANSMITTERS

II.—EXTENSION OF WAVERANGE


TUNING FORK INPUT OF FROM 700~ — 1400~ ACCORDING TO FINAL FREQUENCY REQUIRED
1ST DOUBLING STAGE
1400~ — 2800~ — 2ND DOUBLING STAGE
2800~ — 5600~ — 3RD DOUBLING STAGE
FURTHER DOUBLING STAGES
OUTPUT AT 418 METRES — 836 METRES
LONG WAVE OUTPUTS
DOUBLING STAGE
OUTPUT AT 209 METRES—418 METRES
SHORT WAVE OUTPUTS
OUTPUT AT 104·5 METRES—209 METRES

IN THE MARCONI REVIEW for November, 1929, an article describing a constant frequency fork control for broadcast transmitters was given. In this it was pointed out that the particular apparatus described was designed for wavelengths lying between 209 and 418 metres approximately, when using tuning forks whose frequencies lay between 700 and 1,400 cycles.

To avoid any misunderstanding that these wavelengths are the limiting wavelengths at which such apparatus can operate, it may be pointed out here that the final output wavelength of the instrument can be extended both above and below the wavelengths mentioned by the use of suitable tuning forks and doubling circuits.

This point may be more clearly shown if we consider cases where a final wavelength of 150 and 600 metres respectively are required. In the first case a tuning fork would be used, having a frequency of 976·56 cycles, and a further doubling circuit would be added to reduce a wavelength of 300 metres obtainable with the old equipment to the required 150 metres, and in the second case a tuning fork would be used having the same frequency, but a stage of doubling would be omitted from the apparatus, thus giving the required output at 600 metres wavelength.

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A TUNING FORK CONTROL FOR SHORT WAVE TRANSMITTERS

The equipment developed for the control of broadcast transmitter frequencies by the tuning fork method has been surveyed in the issue of this journal for November last. The present article describes the extension of the same system to the control of transmitters operating on higher frequencies.

THE frequency separation required between any two neighbouring broadcast stations to avoid interference under present working conditions is of the order of 20 kilocycles, that is, each station is allowed a side-band width of 10 kilocycles. Now, if this side-band width be considered in relation to the transmitter carrier frequency, it will be seen that for a wavelength of 300 metres it is 1 in 100, but, for a wavelength of 25 metres, it is only 1 in 1,200. Each station will eventually wish to use as great a sideband width as possible, the limit being set by interference. If the carrier frequency of a station is liable to vary by 1 in 10,000 at a wavelength of 25 metres, and is yet to occupy only its allotted band-width, the sideband width must be reduced by 1·2 kilocycles. The 1·2 kilocycles so lost may well be sufficient to decide whether a multiplex transmission or a high quality simplex channel is practicable. It is therefore desirable to control the transmitter frequency, provided that the cost of so doing does not exceed the value of the freedom from interference or the additional sideband width so obtained.

The Tuning Fork Control System accordingly finds a field of use for this purpose, and the choice of mild steel for the fork material enables the frequency to be deliberately changed over a small range by change of temperature, without loss of stability.

Tuning Fork and Thermostat.

The type of tuning fork and the construction of thermostat used for controlling the fork temperature have been described already in sufficient detail. It will be remembered that the frequency of the tuning fork depends on the material, the dimensions assigned, and in general on the temperature and the amplitude of the vibrations. The first two factors are chosen in design, the second two are commonly used in the final adjustment of frequency. Forks passing out to customers are therefore provided with a summary of the conditions of calibration, and preferably with the actual drive circuit to be used.

The drive chosen has been described in a previous article, and the only changes made have been the result of operational considerations In this new design, meters and fine controls are provided for the supply voltages as in the equipment for the longer wavelengths, but the output potentiometer is graduated in steps of 2 decibels,

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the total drain on the plate supply being indicated, and arrangements are made so that the operator can listen to the fork without disturbing the circuit.

Multiplier Rack.

The panels used for the broadcast control equipment already described, form the basis from which higher frequencies are obtained. The attainment of these frequencies, however, called for certain modifications in the doubling circuits and transformers.

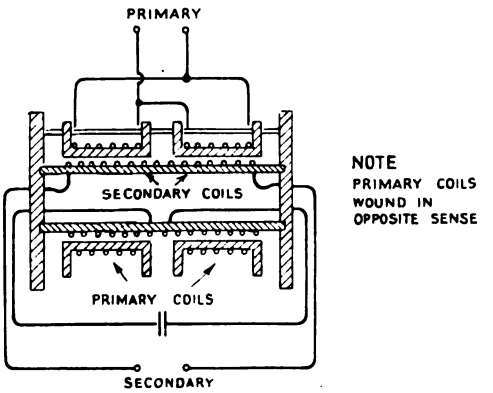

FIG. 1.

The reasons for the changes mentioned were the possibility of resonance at the higher frequencies in the types of transformer previously described, and the danger of oscillation in stages working under the conditions required. The first difficulty could of course be avoided by change of coil design, but there remained the question of keeping a high degree of balance with a different design in the new circuits. The design adopted is illustrated in Fig. 1. The inner coil, split in the centre, forms the secondary. The two outer coils are wound in opposite sense and, connected together in parallel aiding, form the primary. By this means the potential at the extremities is the same, and a symmetrical distribution of capacity currents is obtained. The position of each primary coil can be adjusted over a small range.

The danger of oscillation in high frequency doubler circuits was met by the arrangement shown in Fig. 2. Oscillation frequently occurs owing to weak coupling between the parts of the input transformer secondary allowing the valves to behave as if in parallel. The risk of this trouble is reduced by removing an earth point from the centre of this inductance. In the figure it will be seen that individual grid bias is supplied to each valve, and that the two halves of the winding must therefore be separated by a large condenser. The requisite grid bias is supplied through a resistance of 100,000 ohms to each side. This method has the advantage of causing very slight loss of efficiency, and calls for no fine adjustment.

General Layout.

The photograph of the equipment shows a rack system intended for a station working on about 25 metres. The fork frequency is approximately 1,439 ~, and thirteen doubling stages are used.

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The fork is housed in a separate thermostat, an arrangement allowing greater flexibility to meet varying requirements. This thermostat does not appear in the photograph. The control panel for the thermostat is seen as the lowest panel on the right of the racks, and supports the apparatus for an alternating current supply control. Above this thermostat control panel, the fork drive panel is placed, and above this again, the control and meter panel for the drive. The next two panels on this rack each contain two doubling stages, as do the four lower panels on the left hand rack. On this latter rack, and above the panels mentioned, there are two panels which contain respectively a doubler stage, together with an amplifier and an optional additional amplifier. It should be noted that the first amplifier stage can be changed to a doubler stage without serious mechanical alteration. Both racks are topped by fuse panels from which various panel supplies are distributed, and to which the main supplies are brought. The left hand rack has in addition a meter panel, so that the supply voltages may be checked and the plate current of any stage observed.

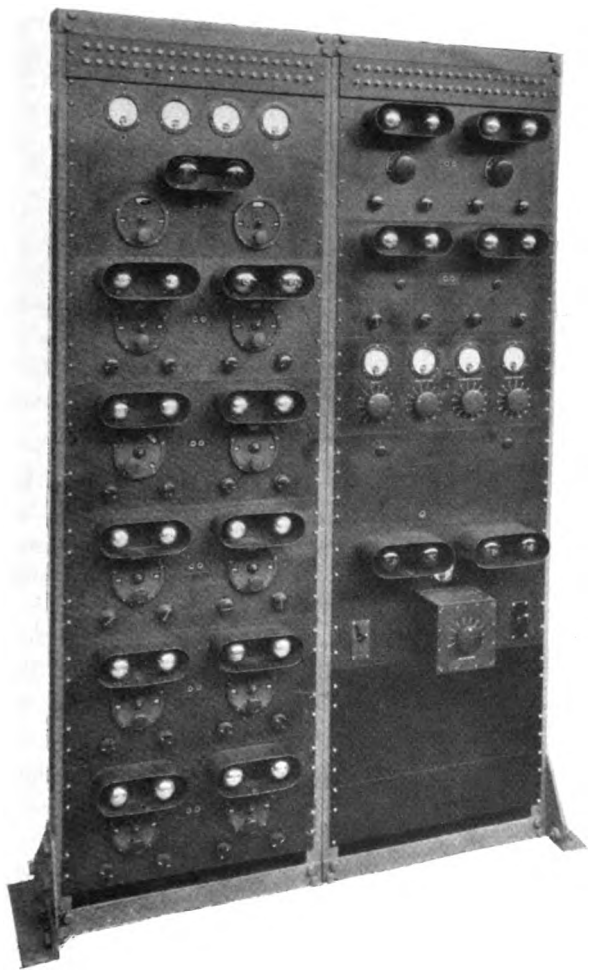

FIG. 2.

As in the broadcast control equipment, individual grid bias for the valves is provided by potentiometers, and the entire structure is at earth potential. The input transformer and secondary tuning condenser of each stage are mounted on two brackets, and a crosspiece. By this means the whole of one tuned circuit may

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be withdrawn together for examination, while the connecting leads are reduced to the minimum length. In so far as is possible, the components of each panel are interchangeable, and are mounted on the same centres, so that the types of spares carried are reduced to a minimum. Should any trouble arise in the working of the thermostat, it is immediately obvious, since the ungettered valves are mounted

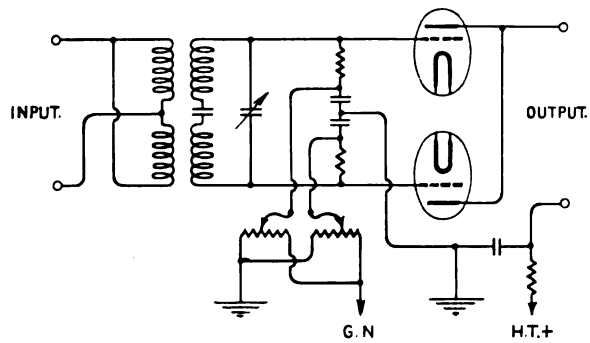

FIG. 3.

on the front of the panel, and a galvanometer shows the working of the relay. The fuses throughout are of the indicating type. Apart from the usual monitoring receiver for the station, the equipment must be available for check when running alone. Accordingly, in addition to the check point in the fork drive circuit already mentioned, a check of the output is provided by arranging the plate current jack of the last doubling stage so that, when a pair of telephones is inserted, any audible frequency modulation is heard as a note. On account of the appreciable high frequency voltage at this stage, very small amounts of modulation are easily detected.

F. M. G. MURPHY.

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A PORTABLE CONSTANT OUTPUT TONE GENERATOR AND VALVE VOLTMETER

FREQUENCY RANGE, 20 TO 10,000 CYCLES PER SECOND

The determination of the transmission efficiency of telephone lines circuits and apparatus is of fundamental importance in telephone engineering. Many electrical and acoustic problems are involved in the efficient transmission of speech and these problems become more severe when efficient transmission of music is also required.

In development of wireless telephone apparatus the radio engineer has to deal with problems similar to those encountered in line transmission systems.

The apparatus comprising the system whether it be land-line or wireless, must give perfect reproduction of the original wave form and also give a uniform frequency response over the audible range, i.e., 50-10,000 cycles. On the other hand, it is frequently necessary to have the frequency characteristics of receiving apparatus, amplifiers, repeaters, filters, etc., so shaped as to compensate for distortion which may be unavoidable in lines or transmitting apparatus.

In order to test the frequency characteristics of such apparatus two instruments are required (i) *a variable frequency tone generator giving constant power output into a constant impedance throughout the audible range ;* (ii) *a sensitive instrument to indicate the loss or gain of the apparatus under test throughout, this range containing a means of calibration in standard units.*

The Tone Generator.

IN any electrical system which is used for the transmission or reception of speech or music, the fidelity of reproduction depends almost entirely on the ability to transmit or receive equally well all frequencies within the audible range. In examining the capabilities of such a system, a tone generator is in general employed to supply a range of pure tones in order that the presence of any distorting influence in the system may be detected. The apparatus must be capable of delivering a pure sine wave of voltage, the frequency of which can be varied continuously over the audible range with the amplitude of the output remaining constant.

It will be realised that such a piece of apparatus has a very wide field of usefulness.

If it is supplied with reliable calibration charts, it can be used as a frequency standard.

It can also be employed in measurements of inductance, capacity and power factor where a source of pure tone frequency is required, and it is necessary to make

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measurements at more than one frequency throughout the audible range, and for testing inter-valve low frequency transformers, telephone transformers, acoustical converters, and various types of transformer iron.

In addition to the above, an instrument of this type is essential in testing the modulation constancy of a radio telephone transmitter.

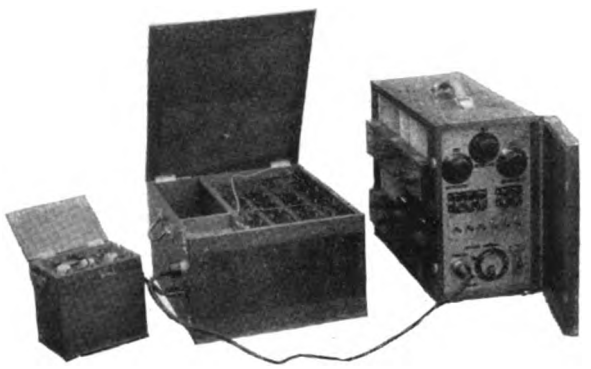

FIG. 1.

When used in conjunction with an audio frequency valve voltmeter the tone generator will be found very valuable for the following purposes.

The measurement of gain in low frequency amplifiers, the loss in low frequency filters, and for taking the characteristic curves and measurement of attenuation for land lines and filters.

Beat frequency oscillators must fulfil several requirements in order to be of the greatest degree of usefulness.

(A) The output wave shape should be a pure sinusoidal function of time.

(B) The output voltage on a constant impedance load should not vary over the frequency range.

(C) There should be a minimum of frequency drift or change in beat frequency of either, or both, of the two oscillators, with changes of temperature, or supply voltages.

(D) There should be no radio frequency oscillations present in the output circuit.

Technical Description.

The Tone Generator is composed of two separate high frequency oscillators, A and B (Fig. 2). One of these (A) operates at a constant frequency while the frequency of the second (B) can be varied by means of the condensers C and D.

The output of the two oscillators act together into a two-stage Push-Pull amplifier in such a way that the two radio frequencies combine to produce a beat, the frequency of which is equal to the difference between the two.

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The relative frequencies of the oscillators A and B are so adjusted that this Beat Frequency can be varied throughout the audible range. The amplifier is capable of giving a power output of 26 milliwatts into a 600 ohms impedance network.

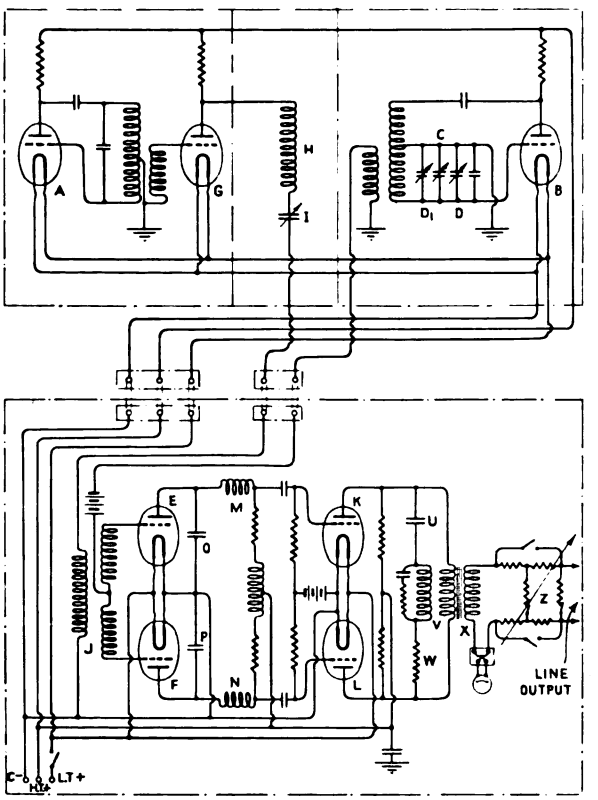

FIG. 2.

The variable oscillator B is coupled directly to the valves E and F which are working in push pull and acting as detectors, the anode bend method of rectification being used.

A coupling valve G is employed to couple the Constant Frequency Oscillator A to the detector circuit, and a special circuit HIJ is interposed in order to suppress harmonics.

The beat frequency from the output of the detector valves EF is then amplified by a single stage resistance coupled push-pull amplifier KL. The two chokes MN and the condensers OP serve effectively to choke back and by-pass respectively the radio frequency components of the two oscillators after rectification.

The output of the amplifier is applied to the 600 ohms impedance network Z by means of a suitable transformer X. The equalising circuit UVW has been introduced to compensate for the non-linear characteristics of this transformer.

A microammeter 0-100 micro-amps. is connected in series with the resistance network Z and the secondary winding of transformer X. This instrument is included to give an indication of the steadiness of the power output over the frequency range and for the zero beat adjustment. The microammeter is operated by a thermo junction.

The maximum power output is of the order of 26 milliwatts and the function of the network Z is to provide a means of controlling this power output. This

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network has an attenuation range of 0-40 T.U.'s and can be varied by steps of ¼ T.U. It is composed of 8 T.U. pads each of which may be put in or out of circuit by means of a Kellog switch. The resistances composing each pad are non-inductively wire-wound in slots on an ebonite former which in turn is mounted on the switch itself.

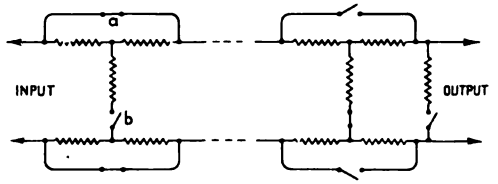

FIG. 3.

Fig. 3 shows the construction of the T.U. pads and method of switching in and out of circuit.

Switches A and B operate together.

The circuit is terminated by a 600 ohms resistance. This resistance is placed in circuit whenever the input circuit to which the generator is connected has an impedance other than 600 ohms.

It will be observed in Fig. 2 that the variable oscillator B has three variable condensers C, D and D' for adjustment. The function of D' is to obtain the zero

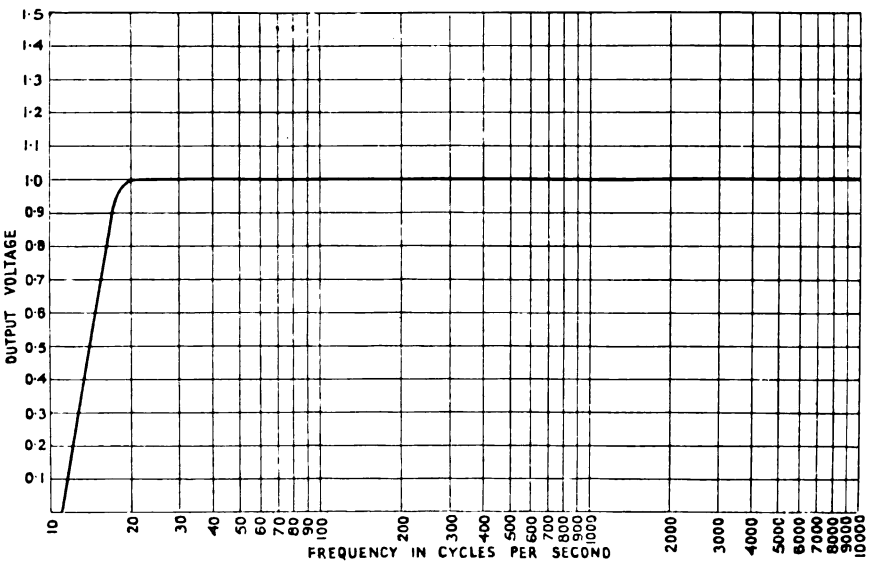

FIG. 4.

beat adjustment prior to setting the generator to work at any desired frequency. The adjustment is very simple and is performed as follows. First condensers C and D are set at zero. The knob of D' is then slowly rotated until the microammeter indicates zero. C and D are then set for the frequency desired by reference to the Calibration Charts supplied.

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Construction.

The Tone Generator may be obtained in two forms: (1) The Rack Type; (2) The Portable Type.

The former is composed of two units, the oscillators being housed in the one, while the amplifier occupies a second. The housing in this case takes the form of wooden cases doubly screened with copper sheet inside and out and intended for mounting in the standard iron frames as used for the Commercial Beam Receiver, etc.

In the Portable Type, shown in the photograph, Fig. 1, the generator is housed in one teak case fitted with handles for carrying. The batteries for filament lighting and anode tension are contained in cases of similar construction.

Alternatively, battery eliminating apparatus for any desired voltage, A.C. or D.C., can be supplied as a portable unit for working from supply mains.

A curve connecting output voltage and frequency for the tone generator is shown in Fig. 4.

The Valve Voltmeter.

This instrument consists essentially of a low frequency amplifier and recifier B, with a high impedance input giving constant amplification throughout the audible range, an indicating instrument being provided in the plate circuit of the rectifier. Included in the apparatus is a single frequency oscillator A, which is adjustable for power output and which may be used either to calibrate the Valve Voltmeter or as a power generator to impress any given power to line up to 12 T.U. also an attenuating network of 40 T U adjustable in steps of $\frac{1}{4}$ T U, a diagram of connections being given in Fig 5, and a photograph of the instrument in Fig. 6.

The apparatus was primarily intended for use in conjunction with the Tone Generator described above for taking the characteristics of aerial land lines, and the network impedance has been designed for 600 ohms. The input and output of this artificial line are brought to plug sockets on the front of the instrument.

A terminal resistance of 600 cycles is across the output of the line and may be inserted by means of the switch.

As will be seen from the diagram the Valve Voltmeter has a transformer input, in series with the primary of which are two 3,000 ohms resistances which reduce the input power to a negligible quantity rendering it suitable for use as a Line Monitoring Indicator and for tapping across a pair of landlines, without any risk of taking an appreciable amount of power from the line. The secondary of this transformer has an equalizing circuit across it to ensure the constant ratio of input to indicated output from 40—10,000 cycles.

The power of the 1,000 cycle note oscillator is adjustable by means of the filament resistance. To this oscillator is coupled a resonant circuit comprising an inductance,

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capacity, thermo milliammeter and 600 ohms resistance in series. A tap is made on the 600 ohms resistance at 15·5 ohms and a switch is provided to short the larger portion.

The oscillator is capable of impressing via the resonant circuit power up to 12 T.U. on the 600 ohms resistance. The plug socket marked Generator output is connected across this 600 ohms resistance. When switch is at " test," it is across only 15·5 ohms.

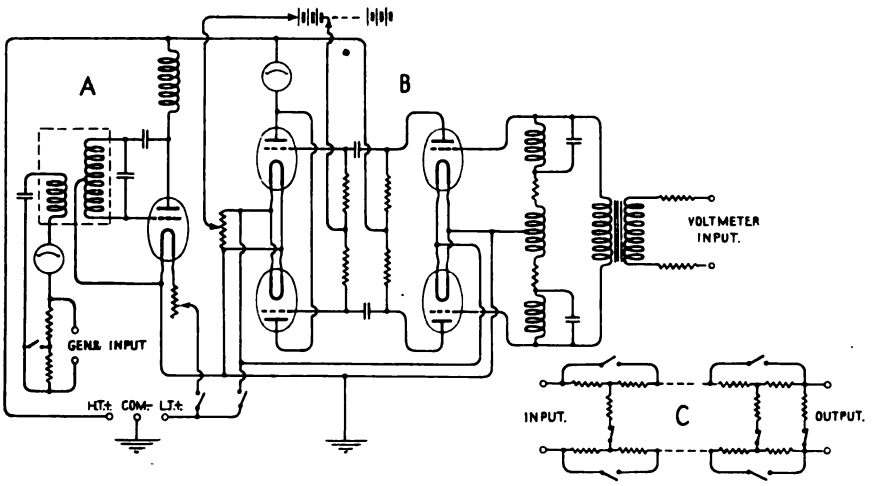

FIG. 5

The Calibration of the Valve Voltmeter.

A standard basis for calibration and measurement has been taken as 1 milliwatt into 600 ohms and is called zero level. This corresponds to a voltage of ·775 volts across 600 ohms or to a current flow of 1·29 ma. Such a small current cannot easily be directly measured, and consequently the same potential drop is first produced by a current of 50 m.a. through 15·5 ohms resistance. In order to do this the switch is put to " test " and the oscillator power adjusted to read 50 m.a. The socket marked " Voltmeter input " is connected with that marked " Generator output " and potentiometer adjusted to give any suitable value on the indicating galvo, say 40°.

The valve voltmeter is now calibrated to read zero-level, i.e., 775 of a volt at 40° on the galvanometer.

The Adjustment of the Generator to Give Zero Level into 600 ohms.

The power of the oscillator is first reduced to a minimum and the switch removed from the test position. The oscillator power is then increased again until the Valve

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Voltmeter reads 40°. The Oscillator output may now be plugged to line if zero level is to be impressed. If, however, less than zero level, say -5 T.U., which is considered the value for ordinary speech from a carbon microphone, is the required power to be put to line, it is only necessary to insert the attenuating line, Fig. 5, C, between the output of generator and the land line and put in the 5 T.U. switch. In this case the terminating resistance is not switched in.

FIG. 6.

The Transmission of a Power to Line Greater than Zero Level.

To do this the Valve Voltmeter is first adjusted to zero level. The generator is then adjusted to give zero level into 600 ohms.

The artificial line is next inserted between the valve voltmeter and the generator (with terminal resistance switched in); the requisite number of T.U.'s representing the required power above zero level, are switched in and the oscillator power increased until the valve voltmeter reads zero level again. The output of the generator may now be plugged to line.

When the Valve Voltmeter is used in conjunction with the variable Tone Generator, the foregoing applies as far as calibrating the Valve Voltmeter for zero level.

The Adjustment of the Variable Tone Generator to Give Power Values above Zero Level.

The output of the artificial line on the Variable Tone Generator (with terminal resistance not switched in) is connected to the input of the valve voltmeter line (with terminal resistance switched in).

The requisite number of T.U.'s representing the power values required are placed in the valve voltmeter line and the tone generator is adjusted until the valve voltmeter reads zero level. The output of the Variable Tone Generator line can now be plugged to landline.

If power values below zero level are required, the variable Tone Generator is connected with the Valve Voltmeter as before through both lines. All attenuation in the Valve Voltmeter line is now cut out, and the Variable Tone Generator line is adjusted to give zero level; the necessary number of T.U.'s representing the power below zero level required are inserted in the same line. The output of this line may then be plugged to line.

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The Measurement of the Incoming Power from a Line.

The Valve Voltmeter is adjusted to read zero level at 40° ; the artificial line (with terminating resistance in circuit) is inserted between Valve Voltmeter and Landline, and the artificial line adjusted so that a reading of 40° is indicated on the galvanometer. The number of T.U.'s left in the line represents the power value above zero level. If the valve voltmeter does not indicate zero level when all T.U.'s are cut out, the incoming power is below 1 milliwatt and the measurement is as follows. A note is made of the reading of received energy, and the local generator adjusted to zero level into 600 ohms ; the artificial line is inserted between generator and Valve Voltmeter (with terminal resistance in), and the line is finally adjusted to give reading of received energy. The number of T.U.'s inserted is the power value below zero level of incoming energy.

The Attenuation of a Line at One Frequency.

This may be measured by two valve voltmeters one at each end of the line. The generator of one is used to put a known power to line, and the other to measure the power received. The discrepancy between the two represents the attenuation of the line.

The Characteristic Curve of a Line over the Audible Range of Frequencies.

The Variable Tone Generator is used at the transmitting end, its power to line adjusted by the Valve Voltmeter to a convenient value. The attenuation of the line is measured at various pre-arranged frequencies throughout the range, and a curve plotted from these readings.

The Gain of a Stage of Low Frequency Amplification at One Frequency.

The output of the generator of the valve Voltmeter is adjusted to zero level, this voltage being applied across the grid filament of a valve, the plate circuit of which is connected through the primary of an L.F. transformer to the H.T. supply, and the secondary across the grid filament of a second valve. From the extremities of a 600 ohms resistance placed in series with the anode and H.T. supply of the latter valve, the alternating voltage is passed via two large condensers and the artificial line (with terminal resistance in) to the valve voltmeter. The line is adjusted until the valve voltmeter reads zero level, then the output of the generator is placed across the grid filament of the second valve and T.U.'s cut out of circuit until zero level is again indicated. The difference between the two adjustments of the T.U. pad represents the amplification of the low frequency circuit, i.e., the first valve and transformer.

The Characteristic Curve of a Stage of Low Frequency Amplification.

The Variable Tone Generator is used as a source of energy. The gain in T.U.'s is measured for various frequencies and a curve plotted. Since the output of the tone

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generator is constant, only one reading with the generator connected to the second valve is necessary.

The characteristic curve of any intervalve low frequency circuit may be taken by this method.

The Loss in a 600 ohms. Impedance Filter.

This may be measured directly at 1,000 cycles by the method adopted for measuring the attenuation of a line except that only one valve voltmeter circuit is required. The generator included in the unit is used as the source of energy.

The Characteristic Curves of a 600 ohms. Impedance Filter.

These curves may be taken directly by the method used for taking the characteristic curve of a land line. The variable tone Generator is used as the source of energy and the land line is replaced by the filter under test.

In taking curves of filters not of 600 ohms impedance a circuit similar to that adopted for taking the curve of amplifiers may be used. The plate circuit of the first valve must, however, pass through a resistance equivalent to the impedance of the filter to be tested. Across this resistance is connected the input of the filter via two large condensers, the output being terminated by a similar resistance to that included in the foregoing plate circuit. (A valve should be chosen with a high impedance in comparison with this resistance.) The grid filament of the second valve is connected across this terminating resistance. The plate of this valve passes as before, through a 600 ohms resistance to the H.T. supply and is coupled to the valve voltmeter.

The curve may now be taken as previously described except that in order to obtain the value from which the various attenuation values at the various frequencies may be taken, the plate side of the plate resistance of the first valve must be connected through a large condenser to the grid side of the grid resistance. It is only necessary to take this reading at one frequency as the curves of the Variable Tone Generator and Valve Voltmeter are constant throughout the range.

The generator of the Valve Voltmeter or the Variable Tone Generator may be used as a means of impressing a known voltage on the modulating circuit of a Telephone Transmitter for the adjustment of percentage modulation. The latter being particularly useful for taking modulation curves through the range.

Inductance, capacity, and impedance measurements may also be made with these instruments.

The foregoing represents a few of the innumerable measurements possible with this apparatus.

C. G. KEMP.

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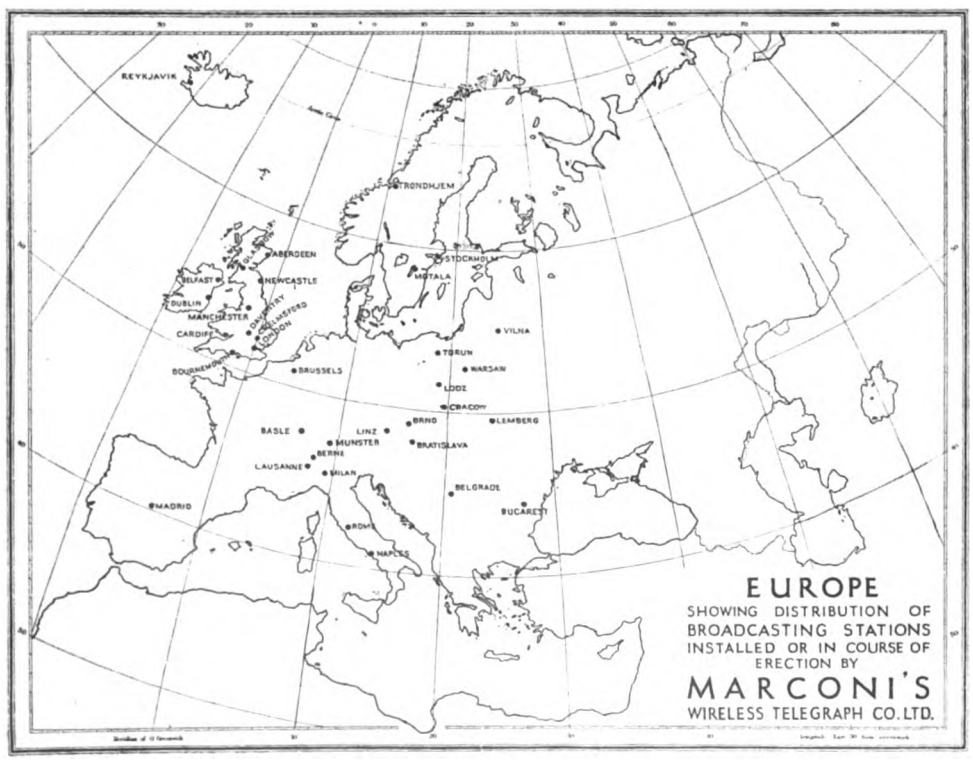
MARCONI NEWS AND NOTES

SWISS "REGIONAL" BROADCASTING PLAN
MARCONI EQUIPMENT

Switzerland is to have a "regional" broadcasting system, somewhat similar to that which is being instituted by the British Broadcasting Corporation, with three high-power stations—in the German, French and Italian speaking sections of the country respectively—and smaller relay stations where required in the principal towns.

The most powerful of the new stations, a Marconi Type "P.B." 60 kilowatt broadcasting transmitter, has already been ordered from the Marconi Company, and is to be erected at Munster, about twelve miles to the north-west of Lucerne. This station will constitute the main "regional" station for German-speaking Switzerland, which is the largest of the three lingual sections of the country.

While it is similar in design to the transmitters at the London "regional" broadcasting station at Brookman's Park, the Munster station will employ greater power, with 60 kilowatts in the aerial, compared with London's 30/50 kilowatts. It will thus be one of the most powerful stations in Europe, a condition rendered



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necessary in spite of the comparatively limited area served by the fact that Switzerland, with its valleys, high mountains, and curious screening effects, is one of the most difficult countries in the world for broadcasting.

Studios in Berne, Zurich, and Basle will provide the programmes for the Munster station, which will be allotted the wavelength of 459 metres.

For "Crystal Listeners."

To provide for "crystal listeners" in the towns, Marconi broadcasting stations of ½ kilowatt aerial power are to be erected at Berne and Basle. These stations are of special Marconi design, with crystal-controlled drive to ensure great constancy of frequency.

The new station at Berne will replace the present Marconi 1 kw. "Q" broadcasting station, which was erected in 1925 and which will later be modernised and re-erected elsewhere to play a part in the "regional" plan. At Basle the new station will be the frontier town's first full-time broadcasting station, the broadcasting service having previously been carried out by the Marconi transmitter at the Basle Aerodrome, which is primarily employed for wireless telephony with aircraft.

The reorganisation of the Swiss broadcasting service on the "regional" basis is expected to be completed in 1931, when, in spite of difficult conditions due to the geographical formation of the country, Switzerland will have a broadcasting system as efficient and complete as any in Europe.

This is the second recent Continental broadcasting reorganisation in which assistance has been sought from the experience of the Marconi Company, in September last year the Company having received an order from Poland for high-power and relay stations designed to give crystal reception throughout the industrial and thickly populated districts of that country.

Italy's Short Wave Broadcast Station.

In accordance with the Italian Broadcasting Company's policy of modernising the Italian Broadcasting system a short-wave Broadcasting transmitting station has been erected near Rome to enable the Italian transmissions to be heard in the Italian Colonies and in overseas countries which are outside the range of the Broadcasting stations operating on the normal broadcast wave-bands of 1,340-1,875 and 200-545 metres.

The new station, which in its main features follows the design of the Marconi short-wave Beam transmitter, has been supplied by the Marconi Company and was manufactured at the Marconi Works at Chelmsford.

The station is now completed and tests were started at the beginning of March when transmission trials on 25.4 metres took place. These tests were observed in the Italian Colonies and in a number of overseas countries.

Reports received from India, Australia, and South Africa remark on the stability, the excellent quality, and the great strength of the Italian transmitter. Reports

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have also been received from New York and these are equally enthusiastic about the emissions from the new Rome station.

From the tests which have so far taken place on 25.4 metres it is already obvious that Italy is now in possession of a short-wave transmitter which will enable the world at large to listen to the artistic programmes which are a feature of the Italian broadcast system.

Arrangements have also been made to enable the transmitter to operate on a second wavelength of 80 metres which is suitable for reception throughout the whole of Italy and neighbouring countries where the normal broadcast wave-band is indifferently received.

The Marconi telephone equipment installed in the new Dover lifeboat.

Wireless for World's Speediest Lifeboat.

The new Dover lifeboat, which with its two 375 h.p. engines is the fastest lifeboat in the world, has been specially equipped for the rescue of aeroplanes which have fallen into the sea. Included in this equipment is a special type of Marconi wireless apparatus which will enable communication to be established with aircraft and other vessels in distress and also with the shore. The wireless installation is known as the Marconi Type X.M.B.1, and is a combined transmitting and receiving set which is totally enclosed, and designed for use under the roughest conditions.

Other boats of the Royal National Lifeboat Institution that have recently been fitted with Marconi apparatus are those stationed at Stornoway and St. Peter Port, Guernsey.

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Flying in Fog.

The report of the London *Times* on the trial flight of the British Government Airship R.100 emphasises the importance of wireless in air navigation. The R.100 was in the air for 53 hours, during which she flew more than the distance from London to Egypt, steering in that time an intricate course with perfect certainty through two days of almost complete fog.

The Aeronautical correspondent of "*The Times*" wrote :—

"Major G. H. Scott, who was in supreme command of the flight, said :—

"We have spent two days more or less in cloud. We flew most of the flight using directional wireless to check our course, with occasional glimpses of the ground as a check on our drift. The main lesson of this long flight over a cloud-hidden England is undoubtedly the certainty with which an airship, alone of man's transport vehicles, is superior to the paralysing influence of fog, and all those in the ship were impressed by this fact.'"

The first remark Sir Dennistoun Burney made when he came off the ship was also on the efficiency of the wireless direction finding apparatus.

"On the first night," he said, "we did not see land, after some rocks by the Channel Islands, until we crossed the Essex coast by Felixstowe the next morning, yet we always knew where we were. There was a spell of 15 hours or more blind flying. Then, when we flew over London yesterday about 10 a.m. we picked out the Tower Bridge through the mist, but the next clear view of the earth was when we saw the fishing fleet off Plymouth at 7 o'clock the same evening."

Wireless Navigation for 15 Hours.

The comments of Mr. Neville Norway, now the Chief Engineer of the Airship Guarantee Company, who has been on board on each flight, were even more interesting in their commercial application. He said :—

"This flight has established clearly that airship travel provides the only means of locomotion in which you can go straight ahead in fog at full cruising speed in perfect safety, and with absolute certainty of making your terminal point. We flew by the aid of directional wireless without sight of land for 15 hours in thick fog at any speed we liked to call for ; no railway, tram or road vehicle, steamer or aeropane has that facility. Our course, too, was a changing one. From the Channel Islands we set out for Brighton, having got our bearings from the direction finders at Croydon and Pulham.

"At the appointed time on our dead reckoning, a glow under the clouds indicated the lights of Brighton, and as the course was reset for

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Marconi engineers ready for a test flight at Croydon.

each town so the glow of its lights in the clouds at the expected time showed we were keeping an accurate course over an invisible earth."

Weather Reports.

Another valuable test made during this endurance flight was the compilation of weather charts on board by Mr. A. Giblett, the officer specially charged with airship meteorological research. He had the weather information sent to the ship by wireless, and from this prepared the same charts as are normally seen by every newspaper reader each morning. So, in addition to exact knowledge of the ship's position by wireless, the probable changes in the weather were forecast for hours ahead.

> "These, on one occasion," Mr. Norway told me," wrote *The Times* correspondent, "showed that the ship was on the wrong side of a storm area, with winds up to 50 miles an hour. There was clear weather indicated on the other side of the storm area, and throughout the first night the ship was driven through the disturbed conditions to find the quieter weather as forecast.

The wireless direction finders at Croydon and Pulham, which provided the airship with its bearings, were supplied to the British Air Ministry by the Marconi Company. They are of the R.g.14 type, specially developed for service in aerodrome ground stations, and during this test flight of the R.100 again justified the implicit confidence which is placed in them by aviators.

Practical Research Work.

The development of wireless for aviation services has been a specialised service of the Marconi Company since it inaugurated the first experiments in ground-to-air wireless communication at the famous Graham-White sheds at Hendon Aerodrome

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in 1912. To-day, the Development Section of the Marconi Company's Air Division operates its own aeroplane, and mobile and stationary land stations, at the London Air Port, Croydon.

With these resources the performance of new apparatus is observed in the air, experience having proved that the results obtained in ground operation are no criterion of what may be expected under the more arduous practical conditions of flying service.

The personnel of the Aviation Department of the Marconi Company consists principally of men with practical flying experience in many parts of the world, who are fully conversant with the problems of wireless operation under flying conditions.

The photograph on page 30 shows two engineers of the Development Section of the Marconi Company's Air Division in flying kit, ready to start a short wave wireless test flight in the Company's "Bristol Fighter." Also in the photograph are the two engineers who operate the mobile station in the motor van on the right, which has complete transmitting and receiving equipment for co-operation with the aeroplane. The van is provided with telescopic masts, and actual working conditions between a machine in the air and ground stations can thus be reproduced. The hut in the background is fitted with long and short wave transmitting and receiving apparatus, and acts as a fixed ground station for tests with aeroplanes.

Sudan to U.S.A.

Short-wave wireless messages transmitted by Major C. Court-Treatt, the British explorer, from a portable Marconi equipment during his recent expedition in the Sudan were received as far afield as the United States of America.

From camps in the least known parts of the Western Sudan, Major Court-Treatt and his party maintained communication with Sudan Government wireless stations

Major Court-Treatt's special short wave Marconi transmitter in operation in the Sudan.

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throughout his year of travel in the jungle making the British Instructional Film "Stampede." Through the Government stations he was in regular touch with the film company's headquarters in London, while on a number of occasions his transmissions, on a wavelength of approximately 30 metres, were heard at distances of more than 5,000 miles in Detroit, Michigan, and Boston, Massachusetts.

The wireless transmitter used was a specially designed Marconi set of extremely small power and weight, the power being supplied by a portable hand generator.

Wireless to the Rescue.

With gales of almost unprecedented force in many parts of the world, and a disastrous submarine earthquake in the Atlantic, the past winter has been an exceptionally difficult one for long distance wire and cable communications. Under conditions of the greatest stress the value of wireless communication in times of emergency was proved again and again.

When the Atlantic cables were damaged by the submarine upheaval in November and ten out of 21 cables were broken, wireless immediately came to the rescue. Large numbers of telegrams were diverted to the transatlantic wireless circuits, and the enormous capacity of the Marconi short-wave Beam stations was proved by the large amount of extra traffic they were able to handle without undue delay.

When the exceptional gales of December interrupted landlines all over the Continent of Europe the only telegraph communication available for a considerable period between certain countries was by means of the wireless service. In Bulgaria for instance, Sofia was for many days completely isolated from all foreign countries so far as landline telegraph communication was concerned. All exterior telegraph communication was, therefore, conducted by means of the wireless service, emergency wireless services being quickly brought into operation for communication with countries to which wireless circuits were not normally available.

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THE MARCONI REVIEW

April, 1930

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THE MARCONI REVIEW

No. 19. *April, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

SPACED AERIAL RECEPTION—
EXPERIMENTS AT TERLING

The partial elimination of fading in the reception of long-distance short wave signals by the use of spaced aerials has been mentioned in THE MARCONI REVIEW, *No. 2.*

The practical application of this method in the case of Transatlantic signals on a wavelength of 21.96 metres which was carried out as a joint investigation by the British Broadcasting Corporation and the Marconi Company is described below.

IN 1927 a series of experiments were carried out by the Marconi Company at Broomfield, near Chelmsford, in order to investigate the advantage of using a number of aerial systems for the reception of short wave signals, these aerial systems being spaced from one another at distances of from five to fifteen wavelengths. It was observed that the fading phenomena observed on one aerial differed from those observed on another aerial spaced some distance away, and that the further the separation, within the limits of the experiment, the greater the independence of the variations of the signal received on one or other of the aerial systems. It was further observed that for a given separation between two aerial systems, the independence was more marked when the line between the aerial systems lay in the direction of the transmitting station than when it was at right angles.

As T. L. Eckersley has shown (MARCONI REVIEW, No. 2 *Loc. cit.*) in a discussion on short wave fading, the advantage of adding, in a statistically independent manner, two signals together independent of phase, reduces the variability of the resultant signal by nearly one half, while the improvement in the signal-to-noise ratio is very large, being certainly greater than 30 : 1. Further, the gain in using three aerials over using two only is at least as great as the gain of two over one.

Preliminary tests carried out at Broomfield with several receivers each connected to an aerial showed very encouraging results, and it was then decided that with the co-operation of the British Broadcasting Corporation further experiments on a larger scale should be carried out on a site leased for the purpose on the estate of Lord Rayleigh at Terling. By the end of the year 1927 masts and buildings had been erected at Terling and preliminary experiments on the type of receiver best

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suited for the purpose had been carried out in the Works at Chelmsford. In January, 1928, the receiving apparatus was installed at Terling, and observations carried out on signals from two aerial systems separated by a distance of two miles. The signals used for the purpose of observation were short wave broadcast programmes from W-2XAD, on a wavelength of 21.96 metres.

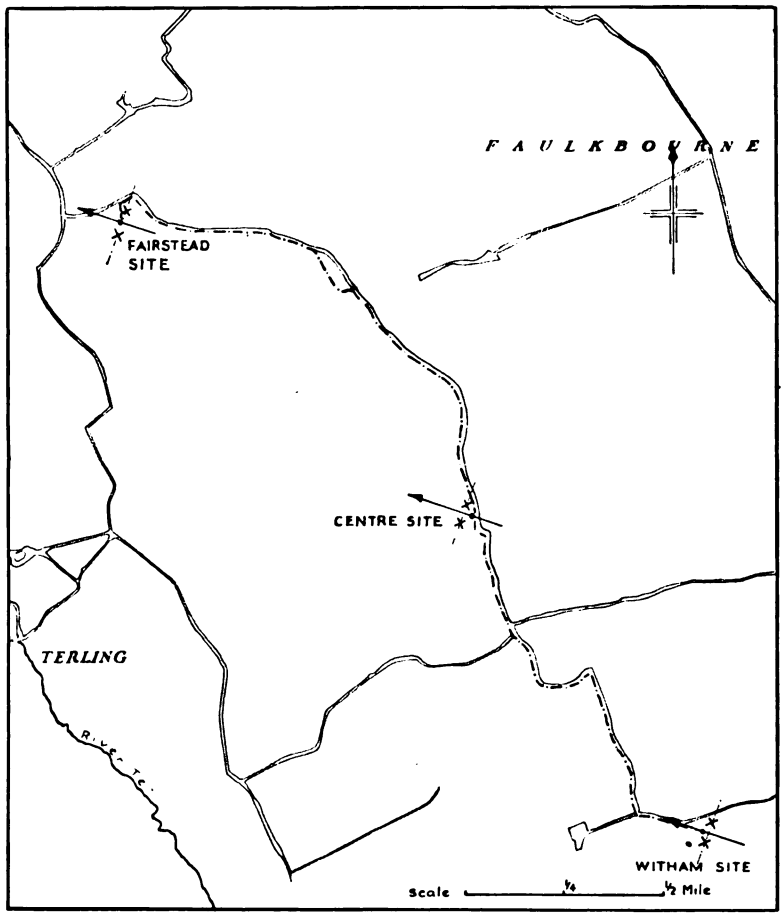

FIG. 1.

Some months later, in view of the promising results obtained in the initial tests at Terling, a third aerial site was added, midway between the already existing systems, and the receiving equipment rebuilt and improved.

It is now proposed to describe the aerial systems and the receiving equipment employed at the Terling receiving station.

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Aerial Systems.

The arrangement of the aerial sites in plan is shown on the Ordnance Survey map on Fig. 1. It will be seen that the three aerial systems are separated from one another by approximately one mile intervals in the direction of New York, and by half mile distances at right angles to New York. It would have been preferable possibly to arrange these aerial systems on one great circle to New York, but the position of the site available would not permit of this.

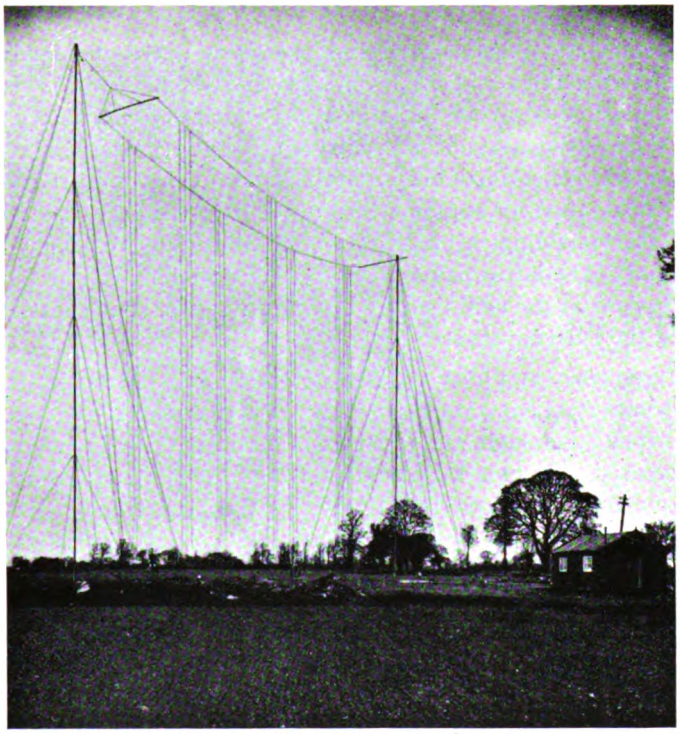

FIG. 2.

The aerial systems in use at Terling consist of small " beam aerials " comprising four Franklin aerial units each of the equivalent height of three half-wavelengths (see Fig. 2). These systems are provided with reflectors, and are directed on a great circle to New York, the true bearing being 289° E. of N. The feeders from the aerial coupling boxes are of the Franklin type, and terminate in a small hut. While the polar diagram of such a small system is not nearly so good as that obtained with the large receiving aerials used at the beam receiving stations, yet the signal strength is noticeably improved by the use of four aerial units, and the signal-to-noise ratio very much improved by the use of reflectors.

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The aerial units used at first were of the Franklin type using " phasing coils " ; but these were later replaced by those of the " uniform type," which proved superior. The aerials were designed for maximum response at a wavelength of 22 metres.

Receiving Equipment.

The receiving equipment employed consists of three double detection receivers, one for each aerial system. The apparatus is mounted on racks and occupies five bays, 75 in. in height by 21½ in. A view of the apparatus in the centre hut is shown in Fig. 3.

The intermediate frequency amplifier of each receiver is divided into two parts, half being situated at the aerial site itself, and the remainder in the centre hut. In this way it is possible to avoid the difficulties which are encountered when many stages of radio frequency amplification are connected in cascade. The distant aerial sites are connected to the centre hut by means of two pairs of overhead transmission lines, one pair being used for applying the output from the beat oscillator to the first detector, and the remaining pair to carry the intermediate frequency signal current to the centre hut. The latter pair is also used for switching on the filaments of the receiving equipment at the aerial site, and provides a telephone channel between the centre hut and the outlying sites.

The high frequency amplifier and first detector unit, together with the first part of the intermediate frequency amplifier, with associated relays, etc., are mounted in a small hut on a rack 30 in. high, and this part of the receiver is left unattended, except when it is necessary to change wavelength settings. The actual operation of searching is carried out from the centre hut, by varying the frequency of the beat oscillator. The operation of setting the high frequency amplifier and first detector on a fresh frequency is easily carried out by passing the signal after the second detector back along the intermediate frequency pair, and listening on a head-set at the actual site.

The intermediate frequency employed is of the order of 1,200 kc., and the whole of the intermediate frequency amplifier comprises in all four screened grid valve transformer coupled stages, the last stage being connected in push-pull in order to avoid overloading. The total measured gain in this amplifier is 110 db., and the mean peak signal voltage produced on the grids of the second detectors is of the order of 20 volts.

The high frequency beat oscillators are three in number, and means are provided so that any oscillator can be connected immediately to any or all receivers. It is possible thus to be able to receive on one frequency only on all receivers simultaneously, or to receive a programme which may be transmitted in two or three frequencies simultaneously.

The method of combining the signals after passing through the second detector is to connect the output terminals of the transformers in the plate circuits of the

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second detectors of the three receivers in parallel. This method proved the simplest and most satisfactory in practice. The quality of the programme and the level may be monitored at any point in the system by means of jacks. The signals then pass through a one-way repeater to the line.

The use of sharply tuned intermediate frequency amplifiers results in a very bad frequency characteristic, due to "side band cut-off." To improve the frequency characteristic of the apparatus therefore an equaliser is employed, which gives a substantially flat characteristic overall frequency up to 5,000 cycles. This is quite sufficient for good quality relaying purposes, and in some cases it is necessary to reduce the band to some 3,500 cycles to cut out noise and interference from some station working close to the received frequency. This is carried out by the use of a low pass filter.

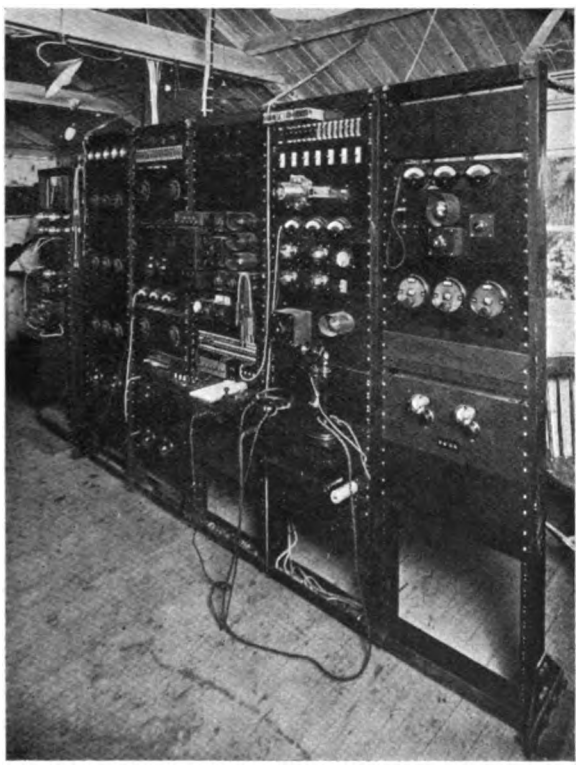

FIG. 3.

The receiver is controlled from a small control table mounted on the racks, and by means of a jack field the output from any receiver can be plugged through to the London Station control room when required. The general lay-out of the apparatus is shown on Fig. 3.

Experiments carried out during 1928-1930.

Observations were carried out during the above period with a view to judging whether the quality of the signals broadcast from the short wave stations of the General Electric Company at Schenectady, N.Y., was good enough for rebroadcast purposes. A two-way radio circuit was set up between Schenectady and Terling in order to carry out tests on intelligibility and to compare observations. This circuit was set up twice a week over a period of some eighteen months, and definitely showed that the spaced aerial system had distinct advantages over reception from one aerial

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only, as the intelligibility when signals were fading badly was such that it was impossible to maintain commercial speech when using one aerial only, while with the use of all three it was possible to carry on conversations with good commercial intelligibility. The results obtained are typified in the curve of Fig. 4.

The transmitter at 5SW, Chelmsford, was used for this speech channel, and the signals from England were picked up at the receiving laboratories of the General Electric Company at Sacandaga Road, South Schenectady.

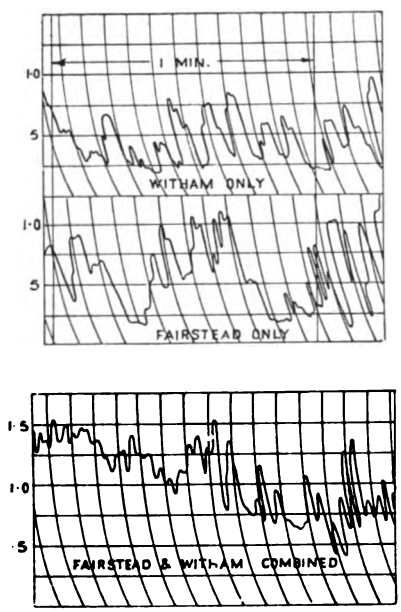

FIG. 4.

With the apparatus which has been described it was found possible to rebroadcast certain interesting events from the United States. The first relay carried out was the landing of the airship Graf Zeppelin on its first voyage to New York, which was regarded by the Press as a great success. Other relays carried out from Terling include the arrival and speech of Mr. Ramsay MacDonald on his visit to New York, the second arrival of the Graf Zeppelin at New York, and a special musical programme on Christmas Day 1929.

Experiments were also carried out on reception of telegraph signals from New York with a view to investigating whether the spaced aerial system could give an improved speed of working when signals were fading badly. Certain modifications were made in the receiving equipment in order to adapt it as far as possible for the reception of telegraph signals, and the high speed signals received relayed via a telegraph line from Terling to Radio House. It may be of interest to note that on one occasion when the lines between Somerton Receiving Station and Radio House were down, the short wave traffic between New York and Radio House was satisfactorily relayed for three hours.

In conclusion it may be stated that the spaced aerial method of short wave reception has proved of considerable utility for the purpose of providing rebroadcast programmes. The equipment at Terling is now in process of being transferred to the receiving station of the British Broadcasting Corporation at Tatsfield in Kent, where it will be installed for relaying purposes.

W. PROCTOR WILSON.

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MARCONI AERODROME TRANSMITTER

TYPE T.A.1

The type T.A.1 Telegraph-Telephone transmitter has been designed primarily as a ground station of moderate power for use at aerodromes in communicating between aerodromes, and from aerodromes to aircraft.

Four of these transmitters have been installed in the new London Terminal Air port at Croydon, and two of these have been recently modified to meet certain requirements.

In the design of the transmitter, special attention has been paid to the question of ease of control and accessibility, and to this end the equipment is divided up into a number of units, and all controls are arranged within easy reach of the operator.

General Description.

THE T.A.1 transmitter itself, together with the aerial and closed circuit components, is shown in the photograph. It consists of an extremely compact transmitter capable of giving a service of C.W., I.C.W. and telephony over a wave range of 800-2,000 metres, and an independent drive system of wavelength control.

The component parts are mounted in an enclosed angle iron framework fitted with metal protecting screens. The controls and instruments are mounted on the front of the transmitter unit.

The range of the transmitter may be taken as of the order of 700 miles in the case of telegraphy, and 400 miles in the case of telephony when transmitting on a wavelength of 1,500 metres.

The installation is given a nominal rating of 4 kilowatts total input.

The complete equipment includes :—

(1) The transmitter unit, comprising :—
- (A) Rectifying unit.
- (B) Independent drive.
- (C) Magnifier circuit.
- (D) Modulating system.

(2) The aerial circuit unit.

(3) The closed circuit unit.

The valves used in the various units are as follows :—

Two Rectifiers	M.R.6.
Independent drive	M.T.4.
Magnifier	M.T.2.
Sub-Modulator	M.T.4B.
Two Modulators	M.T.7B.

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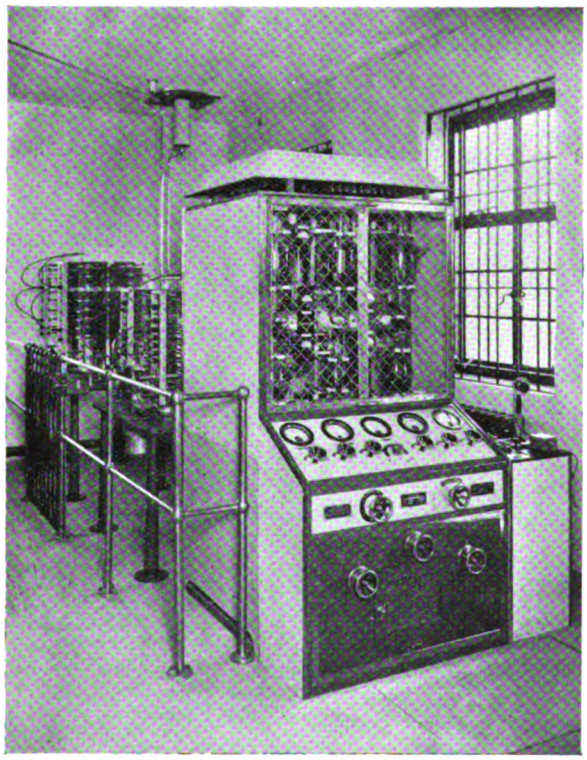
As will be seen in what follows, the two modulating valves act as absorbers during C.W. and I.C.W. transmission.

The Rectifier Unit.

Full wave rectification is used, and the alternating current power supply is controlled by means of an auto-transformer connected between the A.C. mains and the primary of the power transformer. A smoothing choke and two condensers are placed at the bottom of the unit.



Type T.A.1 Transmitter installed at Croydon.

The high tension voltmeter, together with its resistance, is placed in circuit across a smoothing condenser to earth, and serves to discharge the smoothing system automatically when the high tension input is removed.

Two M.R.6 valves are used in the rectifier.

Independent Drive Circuit.

This unit is self-contained in a screened box which slides in the front of the set and under the control panel. Tuning is carried out by means of a variable condenser and two tapped inductances inside the box. The reaction circuit is tuned by a plug-in variable condenser, and the reaction and coupling coils are controlled by handles brought to the front. Resistance is placed in series with the anode of the M.T.4 valve to reduce the High Tension.

Magnifier Circuit and Closed Circuit Unit.

The magnifier valve type M.T.2 is mounted between the modulator/absorber valves in the top rack, and the connections are taken from the valve through insulators at the back of the set to the H.F. table, which carries the main closed circuit inductance, consisting of two inductances in series, one carrying a variometer,

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the other the anti-reaction coil, a variable and two fixed condensers for tuning the anti-reaction circuit. A variable condenser is used for tuning the main closed circuit, and provision is made by means of a link for inserting an extra fixed condenser if required. An H.F. ammeter is mounted on the front of the H.F. table.

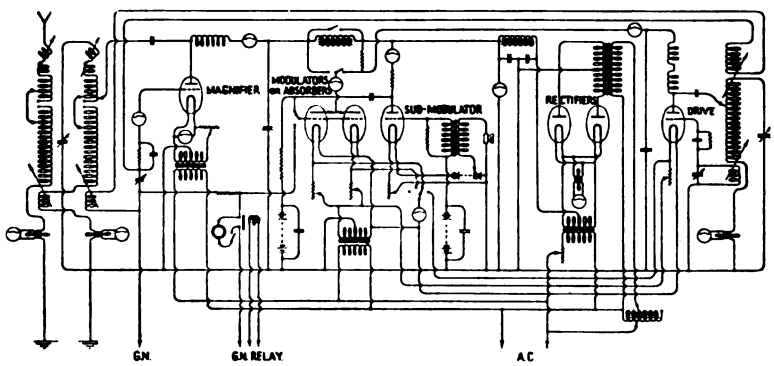

FIG. 1.

Aerial Tuning Inductance Unit.

The two aerial tuning inductances are wound with stranded wire on porcelain insulators. They are tapped at a number of points for coarse adjustment, and one is provided with a variometer for fine adjustments. The other is fitted at the lower end with a coupling coil from which the closed circuit connections are taken.

Signalling Circuits.

(A) Telephony Modulation.

The speech variations are impressed by a microphone on to the grid of the sub-modulating valve, an M.T.4.B, either locally on the control table of the set, or through an amplifier and telephone cable. The anode of this valve is resistance-capacity coupled to the grids of the two modulating valves (two M.T.7 B's), which are prevented from self-oscillation by resistances in their anode circuits. Modulation of the carrier wave is performed by speech choke control to the anode of the magnifier valve.

Continuous Wave and Tonic Train Signalling.

When transmitting on Continuous Wave or Tonic Train the speech choke is shorted, the sub-modulator is not used, and the two modulating valves act as absorbers.

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The principles involved in the method of keying on the absorber system are well known, but may be briefly recapitulated here.

During a space period, a positive potential is applied to the grid of the absorber valves, the anode-filament circuits of which are connected across the oscillating circuit of the magnifier valve. Due to this positive potential the impedance offered

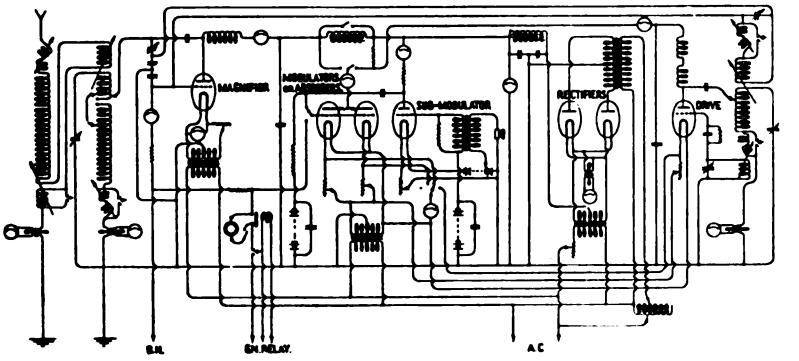

FIG. 2.

by the absorber valves becomes low, and the magnifier ceases to oscillate. At the same time (*i.e.*, when the manipulating key is raised) a negative potential is applied to the grid of the magnifier valve, and the high tension supply to the drive is cut off. The oscillations of the magnifier circuit, therefore, cease abruptly.

During a mark period, a negative potential is applied to the grids of the absorber valves, thereby rendering them non-conductive, and the magnifier is free to oscillate.

For tonic train a motor driven interrupter disc is inserted in the grid circuit of the absorber valves.

The manipulating key operates a creed relay, the contacts of which are in parallel with the tonic train interrupter. The relays and motor operating the interrupter are operated from a 30 volt D.C. supply.

The control panel is placed in a sloping position at the front of the set, and carries all the control instruments.

A diagram of connections of the type T.A.1 transmitter is given in Fig. 1.

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Modifications to Croydon T.A.1 Transmitters.

Certain alterations have been made to some of the T.A.1 transmitters installed at the London Terminal Air Port, and chiefly concern wave change switching and remote control apparatus.

Wave Change Switching.

Three relays, controlled by a master relay, effect the wave changing of the drive, magnifier closed circuit, and aerial circuits, from one of two selected waves about 30 metres above and below the spot wave of 900 metres.

For this purpose additional variometers have been inserted in the drive, drive coupling circuit, magnifier closed circuit and aerial circuits, the anti-reaction coil in the closed circuit has been removed, neutralising being carried out by a neutrodyne condenser.

Remote Control Apparatus.

Relays are provided :—

(1) For switching over from I.C.W. to C.W. on telegraphy.
(2) To control filaments and power supply.

These modifications are shown in Fig. 2.

In addition to the above modifications, delay-action switches have been fitted to all the four transmitters installed at Croydon. These devices cause the valves first to light up with a resistance in series with the filaments, then to attain their working brightness on the automatic withdrawal of this resistance, and finally to receive the correct power supply, each separate action occurring a few seconds later than the preceding one. As the function of these switches is entirely automatic and constant, the life of the valves is lengthened, as is also the starting up of the transmitter simplified.

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THE MARCONI LOW VOLTAGE CATHODE RAY EQUIPMENT

AND ITS APPLICATION TO THE MEASUREMENT AND EXAMINATION OF THE MODULATION AND LINEARITY OF BROADCAST TRANSMITTERS

The apparatus required for examining and measuring the modulation of Broadcast Transmitters, for detecting distortion and for localising faults producing distortion is described with the exception of a Phase Corrector which will be dealt with in a later article to be published in this journal. The methods adopted and the circuit arrangements used for the above investigations are also explained.

THE Oscillograph or Cathode Ray Tube used is the low voltage oscillograph manufactured by Standard Telephones and Cables, Ltd. The tube will not be fully described here since its characteristics and construction are fairly well known. For the benefit of those who are unfamiliar with the tube it will probably suffice to say that an electron beam is produced with an anode potential of 300 volts by the use of a heated cathode. The beam is made to pass through two pairs of deflecting plates known as the " Py " and the " Px " pairs, situated at right angles to one another, for the purpose of deflecting the beam as described later. The beam then strikes a fluorescent screen on the inside of the tube, on which the deflections are depicted. Focussing of the spot is carried out by a fine adjustment of the filament current when the beam is not deflected. The filament current is of the order of one ampere and the anode current is approximately ½ milliampere. A photograph of the Cathode Ray Tube and Box is shown in Fig. 1, while Fig. 2 shows the circuit used for the oscillograph box.

The Cathode Ray Tube Unit.

The Cathode Ray Tube Unit is a metal-lined wooden box containing the Oscillograph Tube socket mounted on a turntable ; the metal screen being connected to an earth terminal. The box also contains apparatus for measuring the deflection of the spot produced by the beam impinging on the fluorescent screen and means for focussing the spot, together with a resistance to protect the tube from damage due to the formation of an arc. A two position key is fitted which lights the filament when operated in a downwards direction and which lights the filament and applies the high tension to the anode when operated in an upward direction. This key should not be used in the upward position unless observations are being taken, as the life of the tube is limited. A push button is fitted in front of the box for operating the H.T. supply and wherever possible this key should be used with the two position key operated to the downward position.

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There are also two press keys fitted for short-circuiting the two pairs of plates. These keys must not be used if the application of a load to the apparatus connected to the plates is likely to cause damage.

The inside of the box and its internal fittings are painted to have a dull black surface.

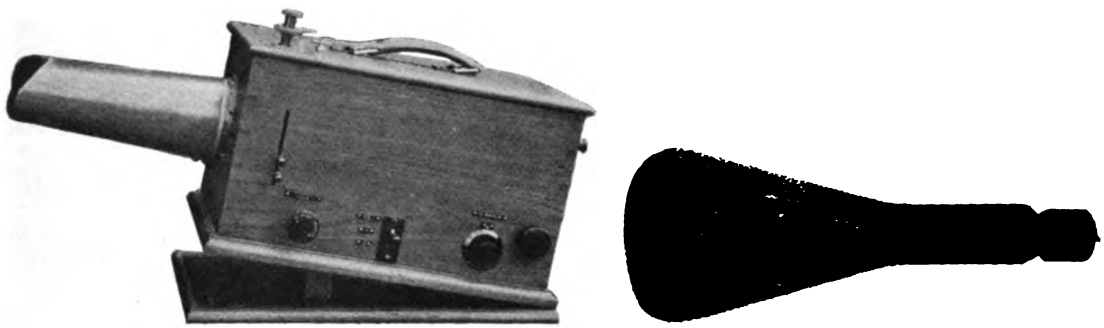

FIG. 1.

The box is light-proof and is fitted with an eye-piece, which is removable. The eye-piece is fixed by means of screws on its periphery and may be placed inside the box for transport purposes. The arms of the measuring device which are described later may also be removed and placed inside the box for transport.

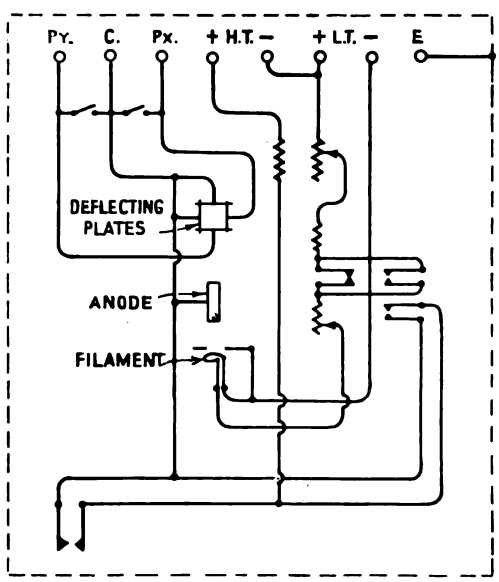

FIG. 2.

An adjustment for the height of the eyepiece is provided by means of a hinged base and a wooden block which may be inserted at any one of a number of fixed points. The block can be carried inside the box when not in use.

Cathode Ray Tube Measuring Device.

The device consists of two horizontal arms with their adjacent edges parallel and mounted in front of the screen of the tube in such a manner that they can be moved vertically (see Fig. 3). The top arm may be moved alone or the two arms may be moved together by rotating

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the upper or lower of the two concentric thumbscrews respectively. The arms are removable in order to facilitate transport and to enable the tube to be taken out of the box.

The movement of the lower arm moves a scale along a fixed pointer mounted outside the Cathode Ray Tube Box, so that the position of the figure to be measured is indicated on the scale, which is engraved in centimetres. The upper arm carries a pointer which moves in a slot in the moving scale and indicates the distance apart of the two arms, thus enabling the height, or change of height of any figure to be measured.

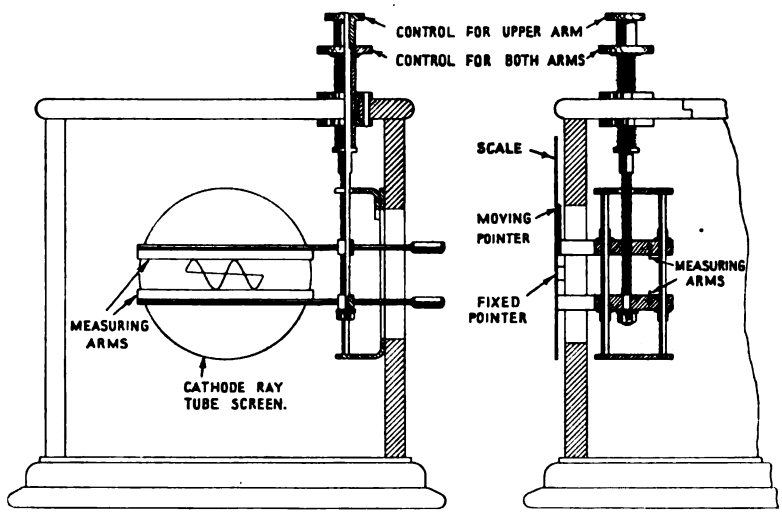

FIG. 3.

A turntable operated by a handle is fitted at the side of the box on which the Cathode Ray Tube socket is mounted, thus making the tube rotatable about an angle of approximately thirty degrees in either direction from the vertical. By rotating the tube the figure depicted on the screen may be brought into a vertical position.

In order to ascertain whether a figure is vertical, a potential should be applied to the " Py " plates, the " Px " plates being short-circuited. This will produce a line which should be vertical, and the turntable should, if necessary, be rotated until such is the case. If, due to the application of another potential to the " Px " plates, the figure then inclines to one side, such action is due to a difference in phase between the two potentials and the tube should not be rotated. The amplitude to be measured will then be as shown in Fig. 4.

The scales are, as stated before, engraved in centimetres, so that the distances measured by the arms may be read off directly from the front of the box.

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If accurate quantitative measurements are to be made it is perhaps advisable to calibrate the tube with D.C. potentials. This calibration is, however, not required, for ordinary work as the tube is generally used for the comparison of two quantities for depicting the shapes of waves, or for the measurement of percentage modulation where the results depend upon the ratio of two measurements.

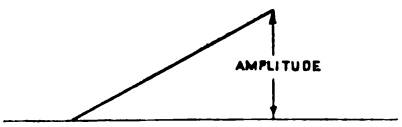

FIG. 4.

The Cathode Ray Box also contains a coarse and a fine filament resistance, together with an anode protective resistance and two keys for short-circuiting the two pairs of plates.

Auxiliary Apparatus.

The following apparatus is required for the examination and measurement of modulation and linearity :—

1 Variable Frequency Oscillator
1 Time Base (for examination only)
1 Rectifier Unit
1 Phase Corrector
1 Pair Radio Frequency Chokes
} For measurement only
1 300 volts battery of dry cells (Ever-Ready Radio or similar battery)
2 6 volts 20 A.H. Accumulators
Lead-covered cable for connections

Variable Frequency Oscillator.

Any source of variable frequency may be used but the Marconi Variable Tone Generator is recommended. This instrument provides a constant output over a frequency range of 20 to 10,000 cycles and was described in the March issue of this journal.

Time Base.

The Time Base (see Fig. 5) consists of a circuit as shown in Fig. 6c of which the chief features are a neon tube, a variable resistance in the form of a diode, and a variable capacity. The apparatus works on the well-known principal by which a condenser charging at a controlled frequency is allowed to discharge through a neon tube, as in Fig. 6a. The frequency is controlled by an adjustment of the capacity of the condenser, and by altering the filament resistance which has the effect of altering the filament impedance of the diode, and consequently controls the rate of charge of the condenser. When the charge on the condenser reaches the striking potential of the neon tube, it discharges through the tube until the condenser charge reaches the point at which the lamp goes out, whereupon the cycle repeats itself. An ideal time base curve is shown in Fig. 6b.

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The potential developed across the neon tube is then fed to the " Px " pair of plates, and, as the discharge time is almost instantaneous compared with the time taken to charge the condenser, the cathode ray beam slowly traverses the screen from left to right as viewed through the eye-piece, and returns to its normal position very rapidly, thus providing an almost ideal time deflection. The deflection of the spot by the time base is very nearly linear with respect to time.

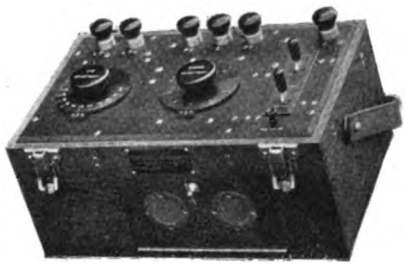

FIG. 5.

The time base circuit is arranged to accept a very small amount of energy from the circuit under investigation and this energy is sufficient to keep the time base pulses in synchronism with the frequency being examined.

It is obvious that if a periodically varying EMF be applied to the " Py " plates, and the time base be used to draw out the figure along a horizontal axis, the actual form of the wave may be seen. It should, however, be appreciated that, since the amplitude of the wave and the length of the time deflection are separately controlled, the wave will appear peaked or levelled, according to the ratios adopted, exactly as a pure sine wave, if drawn on a sheet of graph paper, will be levelled or raised as the " x " and " y " scales are altered.

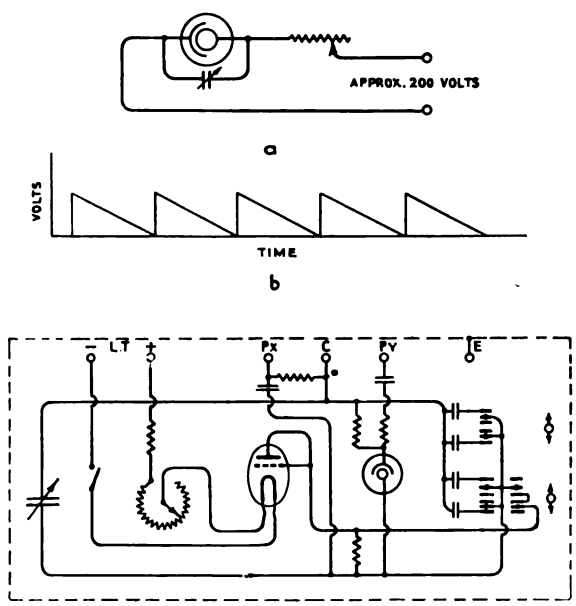

FIG. 6.

With the foregoing proviso, any wave shape may actually be inspected with the aid of the Cathode Ray Oscillograph and Time Base.

The Diode used is a special valve designed to obtain very smooth impedance control.

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Rectifier Unit.

A photograph of the Rectifier Unit appears in Fig. 7, and the circuit is shown in Fig. 8. The Rectifier Unit is screened and consists of a Pick-up Coil in a protective handle to avoid danger to the operator when placing the coil near a high-powered transmitter. The coil is connected to the Rectifier Unit by means of a length of flex, and is tuned to the wavelength of the transmitter by the condensers incorporated in the Unit. The energy received is rectified by the diode valve and the output is taken from the ends of the 10,000 ohm resistance through a lead-covered cable to the Radio Frequency Chokes. Since the Rectifier output is direct current the use of lead-covered cable is admissible. The cable sheath and the screen of the rectifier should be earthed to prevent direct pick-up.

FIG. 7.

A Radio Frequency Choke and bye-pass condenser are incorporated in the Rectifier Unit, and the choke and pick-up coil should be changed for each range of wave lengths.

Coils and chokes are normally supplied for the following ranges :—

PICK-UP COILS.	R.F. CHOKES.
200— 500 metres	200— 300 metres
500—1,000 ,,	300— 500 ,,
1,000—2,000 ,,	500—1,200 ,,
	1,200—3,000 ,,

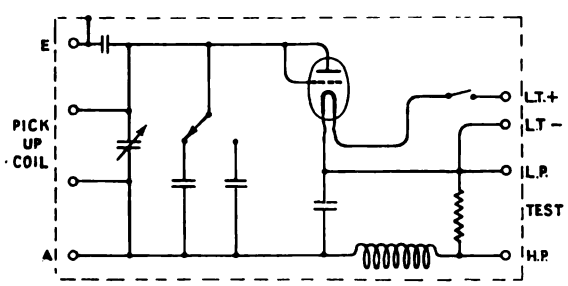

FIG. 8.

The diode used in this unit is a DEP 610 with the plate and grid connected together. The output of the rectifier is substantially constant over the audio frequency range of from 0 to 10,000 cycles when the percentage modulation of the transmitter is kept constant. This ensures accuracy in the measured results, and the rectification provided is practically linear since the diode impedance represents approximately only one fifteenth of the total impedance of the rectifying circuit.

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The Rectifier Unit is arranged so that, if desired, the pick-up coil may be plugged directly into the unit and an aerial may be used to pick up energy. This method will, of course, only provide sufficient output to operate the Cathode Ray Oscillograph at very small distances from the transmitter, and the wavelength range of the instrument will be changed due to the absence of the flexible lead to the pick-up handle.

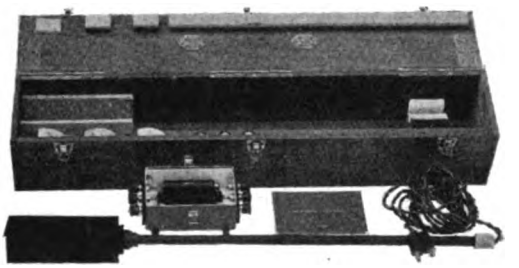

FIG. 9.

The Rectifier Unit includes a box for carrying the handle and for the coils and radio-frequency chokes when not in use. See Fig. 9.

Radio Frequency Choke Box.

A small metal box, containing two radio frequency chokes and a small bye-pass condenser are included for use with the Rectifier Unit. Spare chokes for use on different wavelengths are also carried in the box in which the Pick-up Handle and Tuning Coils are transported. See Fig. 9.

This small box is known as the Radio Frequency Choke Box and is intended to be inserted at the end of the lead-covered cable from the Rectifier Unit and as close as possible to the Cathode Ray Tube Unit, in order to choke back any radio frequency energy which may have been picked up in the leads.

The box should have its earth terminal connected to earth.

Phase Corrector.

The Phase Corrector, which will be described in a future article, is used for adjusting the relative phases of two potentials applied to the tube by advancing or retarding the phase of one of them ; in this case the audio frequency is the potential selected for phase-correcting operations. Such an instrument is necessary in cases where it is desired to witness the effect of a change of phase, or to change a figure from an ellipse to a straight line for purposes of clarification. For instance, a distorted ellipse such as an hysteresis curve is easier to interpret if the figure be reduced to a BH curve, i.e., a line, in cases where the shape of the curve and not the amount of energy expended is being investigated.

The above remarks apply equally to the detection of distortion in amplifiers or radio transmitters.

Method of Examining the Modulated Output Wave of a Transmitter.

The Cathode Ray Tube Unit, and Time Base should be connected as shown in Fig. 10, separate wires being used to join the Rectifier Unit to the Cathode Ray Tube

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Unit as in this case the former is being used for tuning purposes only, and the output is, therefore, radio frequency.

When the Pick-up Handle, fitted with the appropriate coil is plugged into the Rectifier Unit, and the handle is placed near the transmitter so as to pick up energy,

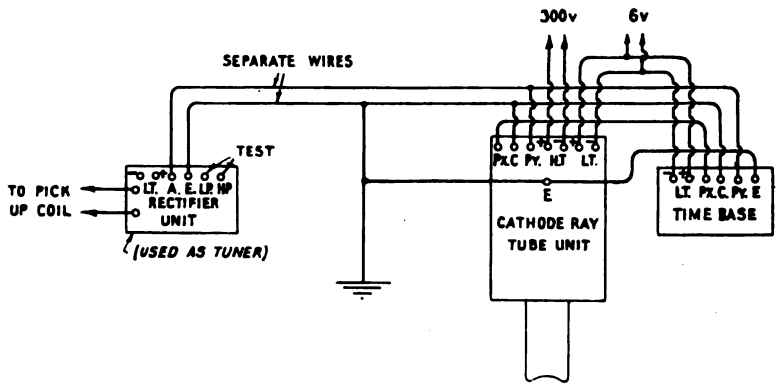

FIG. 10.

the unit may be tuned, the " Px " plates being short-circuited and the Rectifier Unit being switched off.

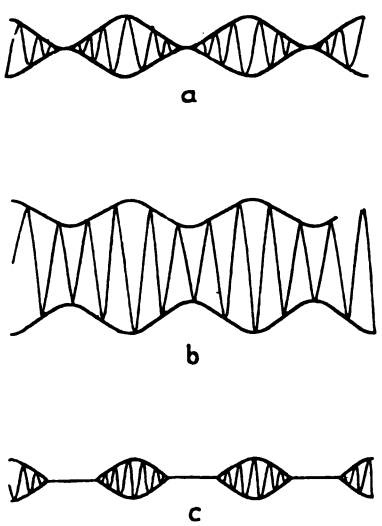

FIG. 11.

Correct tuning is indicated when the spot, which should previously have been focussed, develops into a line and the line reaches its maximum length. The maximum length of the line should always be adjusted by an alteration of the coupling of the Pick-up Coil with the transmitter, and should on no account be corrected by detuning, as the latter method will bring about inaccuracies due to cutting off the outside edges of the side-bands.

When the Rectifier Unit has been tuned, the Time Base should be switched " on," the short-circuit removed from " Px " and the frequency of the Time Base adjusted until it is, preferably, half the frequency of the modulating oscillator. The correct setting of the Time Base is immediately apparent because the modulated wave form will appear as shown in Fig. 11. If the Time Base frequency is half that of the modulating oscillator,

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two audio frequency envelopes will be seen, while with a Time Base frequency of one-third that of the oscillator three complete envelopes will appear.

Measurement of Percentage Modulation.

The Rectifier Unit, Radio Frequency Choke Box, Cathode Ray Tube Unit and the Phase Corrector should be connected as shown in Fig. 12, lead-covered cable being used to join the first two instruments. A separate battery must be used for the Rectifier Unit.

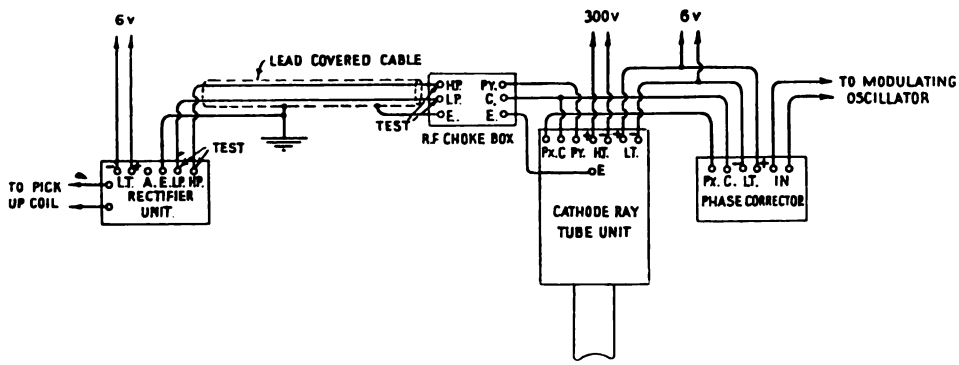

FIG. 12.

The Pick-up Coil should be located so as to pick up energy from the transmitter which should be working in an unmodulated condition, then, with the " Px " plates short-circuited and the spot focussed, the Rectifier Unit should be tuned until the spot reaches the maximum height. If the height attained is not suitable it may be adjusted by an alteration of the coupling between the pick-up coil and the transmitter. As before, de-tuning will cause errors due to filtering out part of the side-bands.

When the tuning is correctly adjusted the tube should be rotated to ensure that the line produced will be vertical. In order to do this, the transmitter should be fully modulated at any convenient frequency, which will cause the spot to develop into a line. The tube should then be turned until the line is perpendicular to the parallel edges of the measuring arms.

The modulation should next be removed and measurement may then be commenced.

The distance through which the spot has moved is proportional to the peak value of the carrier wave and should be measured as follows :—

Short-circuit the " Py " plates, thus bringing the spot to the original position and set the lower measuring arm to this point so that the edge of the arm lies along the centre of the spot. Next, remove the short-circuit from " Py " and set the upper arm

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to the centre of the new position of the spot, care being taken not to move the lower arm. The distance through which the spot has moved may now be read from the amplitude scale on the front of the box. A note should be made of the reading obtained, which should be designated " A."

If desired, the spot, when in position " A " may be brought to the centre of the tube by means of a biassing battery connected in series with the lead from the Radio Frequency Choke Box to the Cathode Ray Tube Unit. This battery should be of the order of 10 volts, and must be connected in the proper sense.

Now modulate the transmitter and the spot will become a line. The upper arm should now be set to the upper end of the line, and the distance between that point and the original central position of the spot should be read from the scale and called " B." This distance represents the peak value of the crest of the modulated envelope. The same procedure is adopted with the lower end of the line, the result, which represents the peak value of the root of the wave, being called " C."

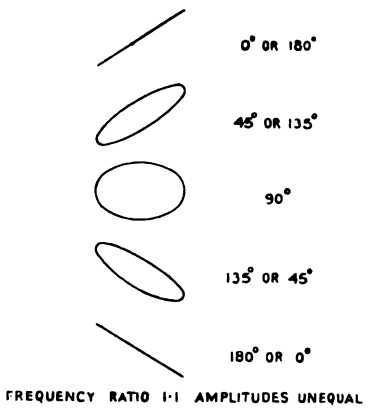

FIG. 13.

The percentage modulation equals

$$\frac{100\ (B-A)}{A} \quad \text{or} \quad \frac{100\ (A-C)}{A}$$

Detection of Lack of Linearity.

If the transmitter is linear (A–C) will be equal to (B–A). It is, however, not easy to detect the existence of small amounts of distortion by this method.

A more satisfactory method is to apply the modulating frequency to the tube via the Phase Corrector. The " Px " plates should now have the short-circuit removed and the Phase Corrector should be switched " on," when an ellipse will appear on the screen.

By rotating the phasing device, the ellipse will become a line which will be straight if the transmitter is linear and will bend over as soon as the transmitter departs from linearity. (For examples of phase relationships see Fig. 13.)

It is thus possible to increase the modulation until the line is just about to bend over, and then to measure the percentage modulation. The result obtained is the maximum percentage modulation obtainable without distortion, at the particular frequency at which the measurement was made.

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Should distortion occur before the expected maximum modulation is reached, the transmitter may be tested, step by step, until the fault is located. The wrong condition existing may then be corrected, and the effect may be noted on the tube.

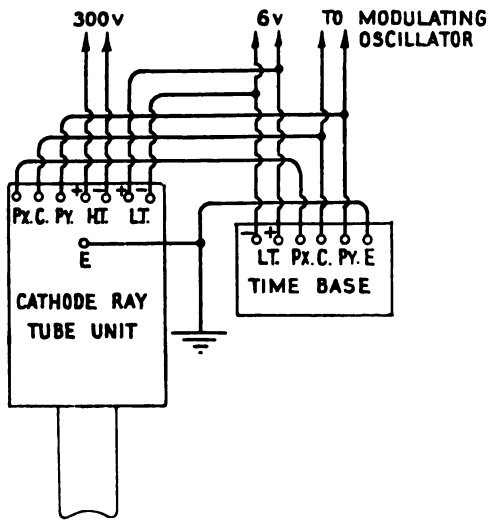

FIG. 14.

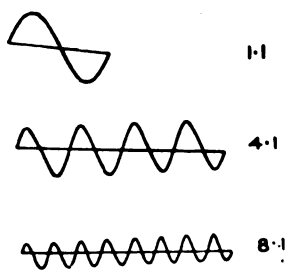

FIG. 15.

Lack of linearity may be due to bad wave-form of the modulating oscillator, and this may be examined as described below.

Examination of Wave-Form.

Connect the Cathode Ray Tube Unit, the Time Base and the Oscillator to be investigated as shown in Fig. 14. Switch on the Time Base and adjust the frequency by means of the condenser and rheostat until it is an exact sub-multiple of the frequency of the oscillator, when a stationary pattern showing the wave-form will appear.

Should the wave-form be impure, changes made to the grid bias, etc., will have their resultant effects thrown upon the screen.

Conclusion.

The foregoing remarks deal with a single application of the Cathode Ray Oscillograph, but it is believed that sufficient has been written to indicate that the instrument may be of very great use for a wide range of investigations.

The author wishes to express his thanks for many valuable suggestions received from various sources.

A short bibliography is appended for the benefit of those who may desire to study the subject more fully.

O. S. PUCKLE.

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SHORT WAVE PROPAGATION

It is pointed out in the following article that the band of frequencies involved in radio transmission can be divided into two classes :—

(a) *Those frequencies corresponding to wavelengths below* 200 *metres, and which are termed short waves.*

(b) *Those frequencies corresponding to wavelengths lying between* 200 *metres and the audic frequencies which are termed long waves.*

Totally differently principles are involved in the propagation of these two types of waves, and the results which may be expected are outlined in a simple manner below.

MANY people have considerable difficulty in reconciling long distance short wave communication with ideas of propagation phenomena gained by a knowledge of long wave working, and the following notes set the case out in a simple manner.

By short waves is meant that band of wavelengths where the waves are considered to be propagated in accordance with the theory of ionic refraction ; this theory can only be applied to those wavelengths where the electrons make many oscillations between collisions of electrons with molecules of air, and this time corresponds to a wavelength round about 200 metres.

Thus short waves concern communication on wavelengths well below 200 metres and the wavelengths near this latter value may be considered as forming a critical wave band which is the dividing line between long and short wave phenomena.

Before considering these short waves it will not be out of place to review briefly our ideas concerning the propagation of waves around the earth. Above the critical band of wavelengths mentioned we can consider that waves are propagated as if bound by the conductors of a transmission line. That is to say, the earth is one conductor and the Heaviside layer another, and the waves travel in the homogeneous insulating medium between these boundaries, and thus we conceive the propagation of waves to follow the ordinary transmission line laws. With this type of transmission the distance it is possible to communicate depends only upon attenuation, for the conception of the Heaviside layer and earth as a spherical transmission line is sufficient to explain the bending of the waves around the whole extent of the surface of the earth. Of course radiation from a long wave aerial may involve an upward ray as well as the horizontal or surface ray. In this case the ray which is sent out from a transmitter upwards, when it meets the upper layer is reflected because the layer is almost a perfect conductor and interference effects from this ray with the surface ray may produce distortion, such for instance as the well-known night effects. In general, however, the surface ray is the only one which need be considered, and therefore since the distance of communication is a function only of attenuation and

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not of bending, the distance it is possible to communicate with a given power will be proportional to the wavelength or rather the wavelength squared. For it is losses in the equivalent transmission line which cause attenuation and since the resistance of a conductor is proportional to frequency squared, the attenuation falls off as the wavelength increases, and thus the curve of distance of communication against wavelength for a given equivalent input is very much as shown by the right hand part of the curve in Fig 1. When wavelengths of 10,000 metres and upwards are reached, it is then possible with normal power to communicate the maximum possible distance on earth, namely, half the earth's circumference. It is not suggested by this that 16,000 metres is the longest wave necessary for communication as longer waves give still more reliable communication at the greatest distance.

Below the critical wave band mentioned, we cannot regard the earth and Heaviside layer as two conducting surfaces because of the very high frequencies involved. The earth is a bad conductor and the Heaviside layer becomes a bad insulating medium. We must conceive the earth therefore as a bad conducting surface in which there will be a considerable loss of waves passing over its surface. The Heaviside layer must now be conceived, not as presenting a suddenly conducting surface, but as an ionised medium in which the ionisation is not constant but increases as the height of the layer increases from the earth. Due to this effect of a gradient in the medium, any wave which is directed at it will not be reflected but penetrates, and because of the gradient of the layer it gets bent, and as long as the gradient increases, the bending will increase. Thus in our conception of radiation from a short wave transmitting aerial we conceive that proportion of energy being transmitted horizontally as being dissipated by earth losses and rays which are being directed from the transmitter at upward angles, as penetrating the upper layer to different degrees depending upon their angle, these rays being bent in their passage through the layer because of the gradient, so much so that in many cases the ray will be returned to earth at some distance from the original source of disturbance. Thus in short waves horizontal, or the surface ray as it is called is of no use for medium and long distance communication but a ray which leaves the transmitter at some upward angle will be used. Hence the chief features for the propagation of short waves over long distances will be those which concern this bending action as well as attenuation. The particular angle which gives the best results is not an easy matter to make a definite statement upon, but it is fairly certain that high angle radiation even if not detrimental is of no value and there is strong evidence that the most useful energy is that which leaves the aerial at a very shallow zenithal angle, just sufficient to avoid earth losses. Hence the tendency of modern designs of short wave aerials, is to avoid those forms which give high angle radiation, such as the harmonic aerial, and to provide forms which propagate a large amount of their total energy at a shallow angle, such as the Franklin Multiple Aerial. Medium and long distance communication on short waves therefore necessitates three conditions being fulfilled.

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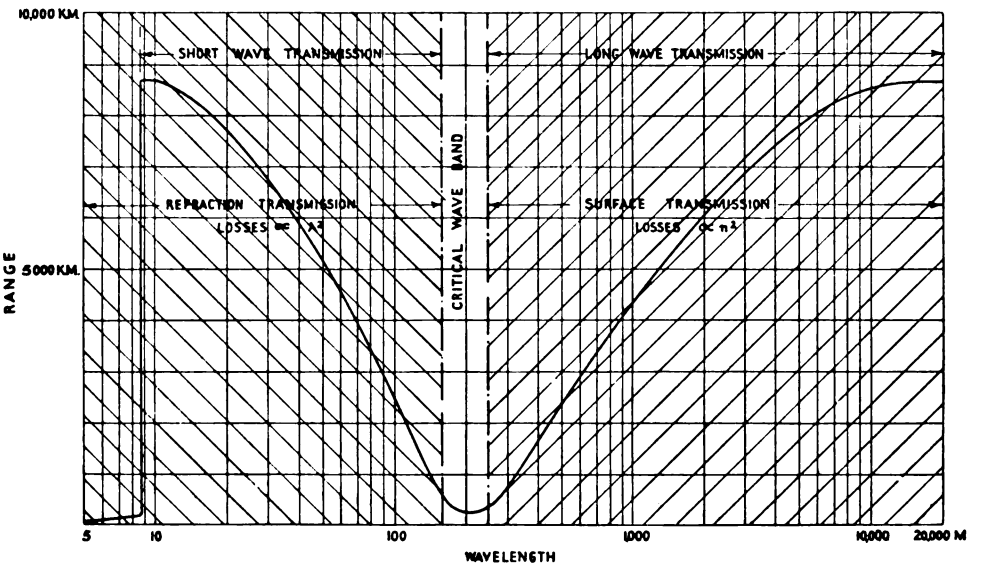
(1) that the attenuation through the layer should be small.

(2) That the bending should be sufficient.

(3) That the power should be radiated at the proper zenithal angle.

Attenuation.

Considering attenuation, this is now not a function of the losses in the equivalent transmission line as it was for long waves, but becomes a question of absorption of the wave as it passes through the upper ionised layer, and it is found that attenuation is proportional, for daylight conditions anyway, to the square of the wavelength ; in



fact exactly the reverse of the long wave attenuation. This is very analagous to the case of the leakage losses in a condenser which are greatest to D.C. and decrease as the frequency is raised. If the distance of communication depended only on attenuation, the curve for communication distance against wavelength would rise from the critical wavelength as the wavelength was decreased. But as the bending effect which will be considered next is equally important we reach a limiting value of short wavelength for communication on earth, below which the range suddenly falls off to the surface ray range. This is shown on the left hand of Fig. 1, where the minimum distance is shown to cut off abruptly at a wavelength near 10 metres.

This does not necessarily mean that 10 metres will be chosen for communication to the Antipodes, for one thing it is too near the critical value and secondly, half the earth is never all in intense daylight, and thus one rarely finds any communication in practice carried on at wavelengths below 14 metres.

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The amount of attenuation is dependent upon the layer conditions and in general will be proportional to the amount of ionisation. Thus during the day attenuation will be greatest because ionisation is greatest. Again in summer the attenuation on any given wave will be greater than in winter for the same reason.

Bending.

Considering now the second feature, it was observed that the bending of the ray is a function of layer ionisation and what is more important, layer gradient ; and to a lesser extent on collision frequency (where the wavelength considered is getting near the critical waveband), and hence it is necessary to study the causes of layer alteration.

The upper layer is to be thought of as a deep belt of ionised gas round the earth in which there is an unceasing movement of electrons and molecules of gas. The ionised molecules are continually re-combining to form neutral particles and owing to the effects of the sun's rays there is a supply of constant ionised particles which vary in number at any particular section of the layer depending upon whether the sun is on that part of the layer or not. The effective ionisation is really the balance of these two effects and hence will be greater at any given point during the day than during the night. The ionisation in itself is not of such importance as the gradient of the ionisation through the layer. For however great the ionisation is, if there is no gradient there will be no bending. Although it is clear that the layer condition and hence the bending is dependent upon daylight and darkness, the alteration of bending effects need not necessarily be, and in fact are not coincident with day and night conditions ; but it is clear also that not only will the time of communication be a factor to consider, but position on earth and season. For instance at a pole in winter there is never any ionisation and hence no gradient, no bending and presumably no communication would be possible through such a region. If one considers the earth illuminated by the sun, one is accustomed to think of half the world being in daylight and half in darkness, with a small rim of twilight as the periphery. Further that the darkness period will graduate from the rim to a point behind the sphere, immediately opposite the sun, where it will be darkest. It should be pointed out, however, that from a bending point of view, although dawn is almost coincident with the " electrical dawn," " electrical night " comes down comparatively slowly and the darkest period from this point of view is at some time previous to the actual dawn.

We can explain the reason for this in the following manner. As can be imagined the outer layer of atmosphere is most rapidly affected by the sun's rays, and hence as soon as daylight appears, the sun ionises the outer layer first which has the immediate effect of steepening the gradient, and hence the bending. The penetration of the sun into the layer as the day goes on ionises the inner layers but the gradient balance is kept although the layer as a whole gets more ionised. Thus considerable

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bending of short waves takes place as soon as the sun rises and continues through the day. Note, however, as the sun rises to its zenith the attenuation will increase owing to the increase of ionisation of layer.

As the sun goes off the earth, the ionisation diminishes but since there is no reason for the outer layer to return to its original state very much quicker than any other layer, the gradient flattens, but very slowly.

The amount of bending will, of course, be a function of the wavelength as well as of the layer condition, and as previously stated, waves below 10 metres are not bent back sufficiently to come to earth again, even during the condition of steepest gradient, i.e. day. Thus with waves up to 10 metres our communication distance is limited to that of surface ray, a few miles, as all upward radiation is either lost in the upper layer or escapes through the layer into the outer atmosphere.

Short wave communication over great distance is carried on therefore on wavelengths above 10 metres, and since the best wavelength depends on layer condition it is clear that to select the correct wave involves a knowledge of layer conditions at the time, season and place being considered and it is outside the scope of this article to deal with it.

Before concluding it might not be out of place to mention the critical waveband. As can be imagined the transition from short wave propagation to long waves is not a sudden one but goes through a phase whose condition shows certain characteristics of both types. On wavelengths lying in this region, between 150 and 300 metres communication is extremely bad. This is owing as mentioned previously, to the collision period between molecules of air and electrons coinciding with the period of the waves pass through the medium and presumably somewhat analagous to a resonance effect in the layer where all the energy of the applied wave is used up in creating internal losses in the layer. Hence one is confined to communication by surface ray and as this has a small range at these wavelengths, the band is only suitable for broadcast purposes, where the object should be to serve a limited area without interfering with the areas beyond.

A. W. LADNER.

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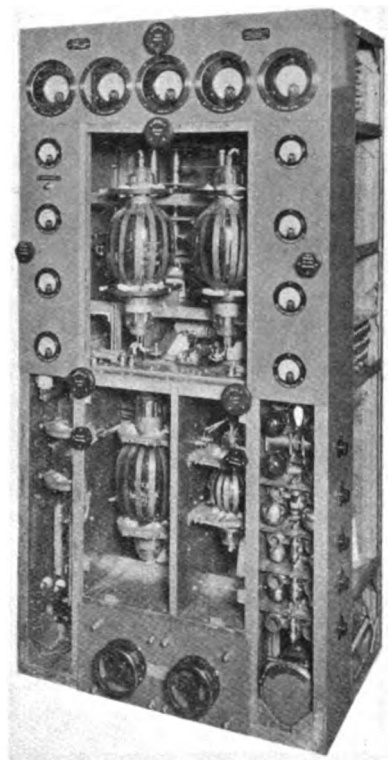
MARCONI NEWS AND NOTES

MARCHESE MARCONI TELEPHONES OVER 9,000 MILES FROM HIS YACHT TO AUSTRALIA

An important new advance in marine wireless telephony has been marked by the success of the experiments recently conducted by Marchese Marconi, in which he carried on conversations from his yacht "Elettra" in the Mediterranean with telephone subscribers in Sydney (New South Wales), London, Montreal, Bombay, Cape Town, New York, Buenos Aires, and Rio de Janeiro.

The first of these conversations, which have aroused world-wide interest among wireless technicians and in the Press, took place on March 21st, when Marchese Marconi spoke, from the S.Y. "Elettra" off Genoa, with Mr. E. T. Fisk, Managing Director of Amalgamated Wireless (Australasia), Ltd., and others at Sydney, over a distance of about 9,000 miles—more than three times the distance of the previous record for a telephone conversation between a ship and a land telephone subscriber.

Two-way conversation from a ship over such a great distance is a remarkable achievement and indicates the efficiency of the new wireless telephone equipment used by Marchese Marconi. This apparatus was constructed at the Marconi Works, Chelmsford, and has been developed to provide an efficient wireless telephone installation to meet the growing demand for a wireless telephone service connecting ships at sea with the land telephone network.



The short-wave telephone transmitter used by Marchese Marconi.

Features of the Installation.

This new short wave telephone installation operates on a wavelength of about 30 metres with a power of 2 kilowatts. A number of new features have been incorporated in the design to ensure the greatest efficiency of operation.

One of the most important of these is the provision of a special valve drive, corrected for temperature variation, which, while equal in constancy to a crystal drive, eliminates the disadvantages inherent in the crystal type of control.

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The complete installation is compact and can be placed in an ordinary cabin. It is simple in operation and promises to provide an efficient wireless telephone service for ships at sea over almost any distance.

"Conversation Remarkably Clear."

In the following telegram received from Mr. E. T. Fisk after his conversation with Marchese Marconi the capabilities of the new set are indicated :—

> "My conversation from Sydney with Marchese Marconi on board his yacht "Elettra" at Genoa has caused great interest here. The conversation was remarkably clear and as easy as talking by ordinary telephone between Sydney and the suburbs. This result is particularly notable because Marchese Marconi's yacht is a vessel of only seven hundred tons, and consequently both the power and the antennæ which could be employed on board were severely limited. This is a world's record for duplex radio-telephone conversation between ship and land."

Opening the Sydney Exhibition.

In the course of his wireless telephone talk with Australia Marchese Marconi received a request to take part in the opening of the Annual Electrical and Wireless Exhibition at Sydney by sending a wireless signal from the "Elettra" in the Mediterranean to Sydney to operate a relay which would switch on the lights in Sydney City Hall and so open the Exhibition. This he agreed to do and the demonstration took place on March 26th, proving most impressive.

By means of the wireless telephone set on the S.Y. "Elettra," Marchese Marconi also spoke to the chairman of the Exhibition. The following message from Marchese Marconi to the Exhibition explains how the operation of lighting the lamps from the Mediterranean was achieved.

> "It affords me great pleasure to perform the ceremony of officially lighting the symbol of the Red Seal Scheme inaugurated by the Electrical and Radio Development Association in New South Wales.
>
> "The switches for lighting the Sydney City Hall will be operated by wireless from the yacht 'Elettra,' which is at present in the Mediterranean at Genoa.
>
> "By the act of depressing a key on board the 'Elettra' I shall automatically release a train of waves from the Beam wireless station in England, which will be practically instantaneously received at Rockbank, Victoria.
>
> "The impulse will then be relayed automatically through 550 miles of overland wire to the Sydney City Hall where it will cause the power to be switched on to the lights.
>
> "It is not more than thirty years since I transmitted the first faint wireless signals across the Atlantic Ocean and to-day we demonstrate that it is possible by wireless to bring powerful currents into operation at the other ends of the earth.

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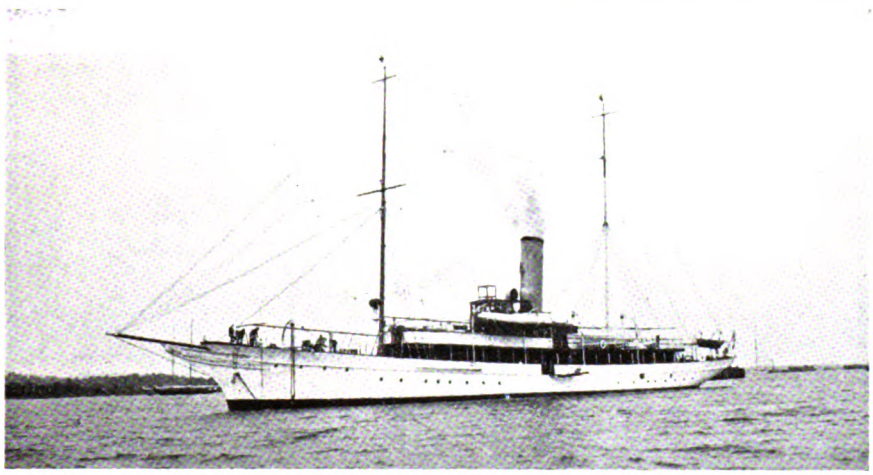

S.Y. "Elettra."

"On your chairman's request which will be transmitted to me by Beam wireless I shall set in motion the apparatus on the 'Elettra' which will automatically actuate the switches in the Sydney City Hall and so inaugurate the Red Seal Scheme.

"I heartily congratulate Australia on the strides made there during recent years in world-wide wireless communication."

Following the opening of the Exhibition, Marchese Marconi spoke direct from the S.Y. "Elettra" to Sydney, and Reuter's correspondent on board the yacht was also handed the telephone and conveyed oral greetings to a gathering of journalists in Sydney.

Particulars of the pioneer work of Marconi's Wireless Telegraph Co., Ltd., and the Marconi International Marine Communication Co., Ltd., in wireless telephony at sea will be found in No. 12 of the MARCONI REVIEW.

Wireless for Air Yacht.

The three-engined Supermarine Metal Monoplane flying boat just purchased by the Hon. A. E. Guiness, the first of its kind built in Great Britain for a private owner, carries a comprehensive Marconi installation.

This air-yacht, which has a cruising speed of 100 miles per hour, will normally carry a crew of three and six passengers. The Marconi equipment consists of a powerful transmitter and receiver, a Direction Finder, and a broadcast receiver. The transmitter and receiver are of the Marconi ½-kilowatt A.D.8 type which will provide reliable communication between the air-yacht and aerodromes, coast stations, and

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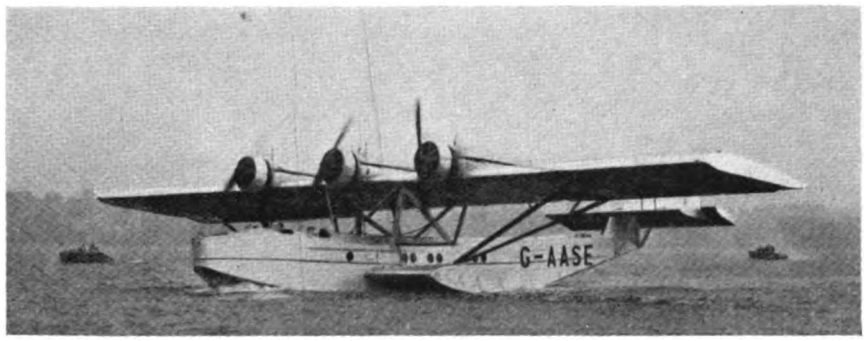

The Hon. A. E. Guiness' supermarine air yacht, equipped with Marconi apparatus.

vessels on the high seas, up to 400 miles under normal conditions either on telephony or telegraphy.

The Direction Finder is the trusted friend of aerial navigators in fog or under conditions of bad visibility and the fitting of a Marconi Direction Finder Type A.D.16 illustrates the thoroughness with which the navigation equipment of this air-yacht has been studied.

The broadcast receiver is a Marconiphone Type 35 instrument which will provide an enjoyable source of entertainment for the crew and passengers and will enable them to choose the best of the broadcast programmes within a wide range.

Wireless communication can take place either during flight or when the machine is resting on the water. To meet both purposes two aerials are provided, one of the trailing type for use in the air and the other of the fixed type, attached between the wings, for use on the water.

This is the second air yacht owned by the Hon. A. E. Guiness to be equipped with wireless apparatus by the Marconi Company, an A.D.6 transmitter and receiver having been installed in his Supermarine " Solent " flying boat in 1927.

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THE MARCONI REVIEW

May, 1930

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THE MARCONI REVIEW

No. 20. *May, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI REFLECTION SOUNDING DEVICE

Reflection sounding, that is to say the method of determining the depth of water under a ship by measuring the time taken for a disturbance in the water to travel from the bottom of the ship to the bottom of the sea and thence back again to the bottom of the ship, was first proposed many years ago, but has only recently become a practicable proposition.

There are many well known and effective methods of transmitting a suitable disturbance through the water, and also of receiving the reflection on its return, but the problem of measuring accurately the very small interval of time between the transmission of the disturbance and the receipt of the reflection presents considerable difficulties.

These difficulties have been largely overcome in the Marconi Sounding Device, a description of which is given below.

THE velocity with which a compression wave travels through water is well known, and is constant under given conditions of temperature and salinity. For the purposes of navigation this velocity can be taken as 4,900 feet per second, the variations from this velocity being very slight on the high seas. In unusually fresh water, such as the Baltic, or in unusually salt water, such as the Mediterranean, small errors may be found, but these errors are well known and are constant. When using an instrument calibrated for average ocean water, the soundings recorded when in the Baltic would be four per cent. more than the actual truth, and in the Mediterranean they would be one per cent. less than the actual truth. For the ordinary purposes of navigation there is but little interest taken in depths exceeding 100 fathoms, and at this depth the time to be measured is 245 milli-seconds. The time to be measured in, say, 5 fathoms is only 20.5 milli-seconds. These measurements only give the depth of water beneath the instruments, so the depth of the instruments under water has to be added to the depth of water under the instruments to obtain the depth of water measured from its surface, which is the measurement given on the charts.

Next in importance to the problem of the measurement of very small periods of time, comes the problem of avoiding the receipt of false signals, that is to say signals

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which are not the true reflection of the original transmission. This problem is analagous to the wireless problem of selective tuning, and the solution must depend upon the nature of the disturbance originally imparted to the water. If this disturbance is rhythmic then the properties of resonance can be made use of to provide some degree of selective tuning, if it is strictly aperiodic the effects of resonance will not be available.

If shallow depths are to be measured, the total period during which each transmission is to last must be very small. A transmission lasting 1/40th of a second will hinder the reflection being distinguished from the transmission at any depth less than 10 fathoms (below instruments) because the first waves of the reflection will have reached the receiver before the last waves of transmission have got away. Therefore, the frequency of the transmitted disturbance must be high if sufficient crests are to be made use of to allow the full value of resonance to be obtained.

For instance, if it is required to measure five fathoms below the instruments, and if it is assumed that five crests are sufficient to develop the effects of resonance adequately for selective purposes, the convenient limit of frequency is 400 per second.

In practice there is usually a persistence of comparatively feeble oscillation after the main part of the transmission has ceased, which sets the limit of frequency even higher. Probably about 1,000 per second is the least which is desirable for sea-going purposes, unless the transmitter and receiver are widely separated.

Definite advantages can be gained by increase in frequency, the limit beyond which the frequency cannot profitably be increased being reached when the attenuation of the wave—which increases with its frequency—becomes serious.

The chief advantage of high frequencies for sounding work lies in the fact that directional transmission becomes practicable. The factors which make for directional transmission are naturally proportional to the wave length, and at high frequencies the mechanical dimensions of a directional transmitter become easily manageable. The optimum frequency for this purpose is probably about 40,000 per second, which corresponds to a wavelength through the water of 3.7 centimetres. At frequencies above this figure the attenuation becomes serious, and at substantially lower frequencies the apparatus necessary to produce highly directional effects becomes too large for convenience.

Accuracy of Reflection Sounding.

The degree of accuracy with which soundings can be measured depends upon two things—the certainty with which the velocity of the compression wave through water is known and the accuracy of the chronograph employed.

For all practical purposes, human knowledge of the first of these two is accurate enough. The temperature correction is negligible, and if due regard is paid to what may be called the " Baltic " and " Mediterranean " corrections, errors due to this cause will be less than 1 per cent., an error which is of no account to the navigator.

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It is impossible to take a sounding by other means with sufficient accuracy to check observations, and errors of 1 fathom in a hundred, or of 7 inches in 10 fathoms, are not very serious.

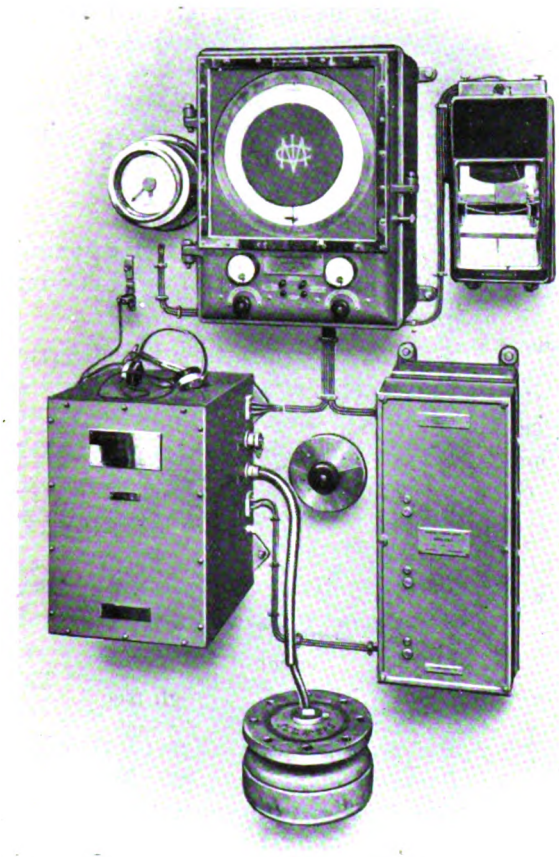

FIG. 1.

The accuracy of the chronograph depends upon its construction and on the ease with which its scale can be read under seagoing conditions. The instrument supplied by the Marconi Company is peculiar in the latter respect because its pointer is brought to rest at the sounding as measured and is held there for several seconds, so that no errors can arise in reading the instrument. The accuracy of the chronograph itself is dependent on its own behaviour, that is to say on the constancy with which its moving parts can maintain their speed and on the limitation to some insignificant period of the time taken for it to respond to the impulse received from the transmission or from the reflection. Errors of this nature are further reduced by setting the error due to the time of response to the impulse of transmission in opposition to the error due to the time of response to the impulse of reception. The resulting total error is due to the difference between two periods, both insignificant, and the difference between these two may be properly regarded negligible.

Careful examination of the completed instrument shows that the shortest period of response of the moving parts is not less than 1 milli-second, and that the longest period of response does not exceed $2\frac{1}{2}$ milli-seconds, leaving a maximum possible error of less than 1 fathom. So great an error as this will only occur when sounding in

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considerable depths, about 300 fathoms, and it becomes progressively less as the depth to be measured decreases.

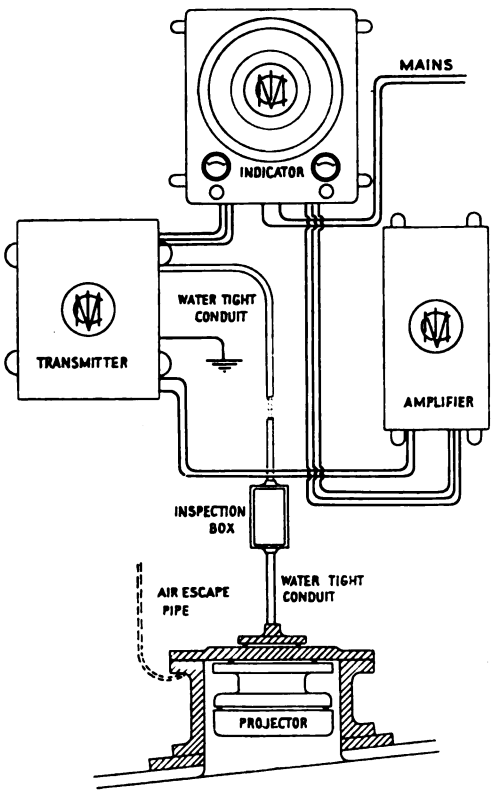

FIG. 2.

A tell-tale device is provided which shows that the revolving parts of the indicator are moving at their proper speed. This device will give warning if the speed is rather less than 1 per cent. in error. A photograph of the instrument is shown in Fig. 1, and a general layout in Fig. 2.

Technical Description.

The electrical and mechanical arrangements of the Marconi Indicator are as follows :

The indicator, a schematic diagram and diagram of connections, of which are given in Figs. 3 and 4, is essentially a special form of chronograph adapted to the purpose of showing the depth of water, its scale being graduated from 0 to 350 fathoms.

The driving portion is a small motor, mounted with its shaft vertical, which drives a double reduction worm gear enclosed in an oil-tight box. The motor speed is 2,040 r.p.m., and the first reduction shaft (30 to 1) drives the flywheel at 68 r.p.m. This speed is chosen so that one fathom on the scale shall correspond to one degree movement of the pointer. The second reduction shaft (17 to 1) drives the cams which cause the installation to repeat the series of operations necessary for taking a sounding four times a minute.

The maximum time between the transmission and the return of the reflected signal is a little less than one second. About three seconds are required to restore the whole arrangement to its starting position, and the pointer remains stationary at the depth for 10 seconds or a little over.

The flywheel carries a small pot magnet at its centre, which has two windings connected to the stationary parts of the indicator by four slip rings and brushes, two brushes to each slip ring. The brushes are round carbon rod backed up by light

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spiral springs. The brush holders are held in place by two screws each, which are inserted from the front end of the brush holders.

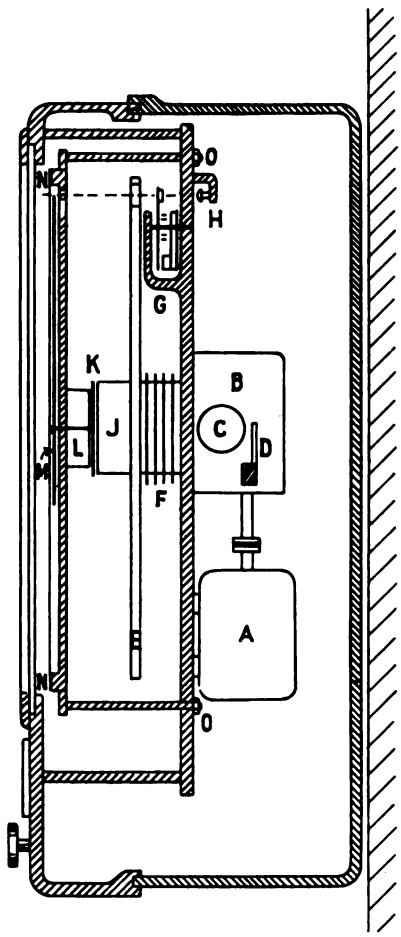

FIG. 3.

A. Motor.
B. Gear Box.
C. Cam pack.
D. Cam contacts.
E. Flywheel.
F. Slip rings.
G. Time check.
H. Time check lamp.
J. Drive magnet.
K. *Disc.*
L. Brake magnet.
M. Pointer.
N. Scale.
O.O. Air gap adjustment.

In front of this magnet, which is called the Drive Magnet, is mounted a stationary magnet called the Brake Magnet. In between these two is a thin iron disc carrying a phosphor bronze spindle running in agate bearings. This spindle carries the pointer mechanism. The end play of this disc is one-hundredth of an inch, and the spindle is free in the agate bearings.

The circuits of these two magnets are controlled by three small relays, known as the change over relay, the drive relay, and the brake relay. Each of these has two windings, one for operating and the other for a hold-on. The change over relay has two sets of contacts, the others one each.

In order to destroy all traces of residual magnetism in the relays and brake and drive magnets, arrangements are made to send a momentary reverse current through their windings at the end of the series of operations required for taking a sounding.

The valve in the indicator is used as a relay, its anode current being used to work the relays and magnets and its grid being controlled through a special circuit by current in the anode circuit of the last valve in the amplifier. When at rest the anode current of the indicator valve is reduced to zero (less than 0.2 milliamps) by negative grid bias. The special circuit mentioned above prevents the anode current from being more than momentary.

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Operation of Indicator.

The sequence of actions taking place in the indicator is as follows :

In the position of rest the change over relay tongues connect the drive winding in the valve circuit, also the operating coil of the change over and drive relays.

At the moment of transmission there is a surge of current in the anode circuit of the indicator valve. This causes several simultaneous sets of movements.

(A) The drive magnet seizes the pointer disc, and therefore it begins to rotate.

(B) The change over relay operates, removing the drive circuit from the valve circuit and replacing it by the brake relay operating coil. It also closes the dimmer contacts.

(C) The drive relay closes and completes the circuits through its own hold on winding, the drive hold on winding, and the change over relay hold on winding. This keeps the change over relay locked in its new position, and also keeps the disc and pointer locked to the pot magnet on the flywheel. The pointer therefore continues to travel round the scale. The pull of the drive hold on is adjusted by shunting it with a variable resistance. This is a semi-permanent adjustment.

In order that all the above movements shall be quick enough, all the windings are energised at 105 (or 210) volts. The value of the current is kept down to the correct figure by permanent resistances, except in the case of the circuits operated by the anode current of the indicator valve.

As soon as the reflection is received a second surge of current takes place in the anode circuit of the indicator valve, which now includes the operating circuit of the brake relay. The brake relay therefore closes (if the current is sufficient) and the following simultaneous effects are produced.

(A) The brake relay hold on winding is excited, thus locking the brake relay.

(B) The brake magnet winding is excited, and kept excited, so that the disc and pointer are captured from the drive magnet, against the attraction of its hold-on, and are held locked until the time comes for the various circuits to be demagnetised.

The distance travelled by the pointer is a measure of the time between transmission and the return of the reflection. As the speed at which a disturbance travels through the body of water (not along its surface) is well known, the scale can be graduated so that the pointer indicates fathoms.

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Working of Pointer.

The following arrangements are made for working the pointer :—

The pointer is returned to zero by two helical springs pulling round a small drum held to the pointer spindle by a grub screw.

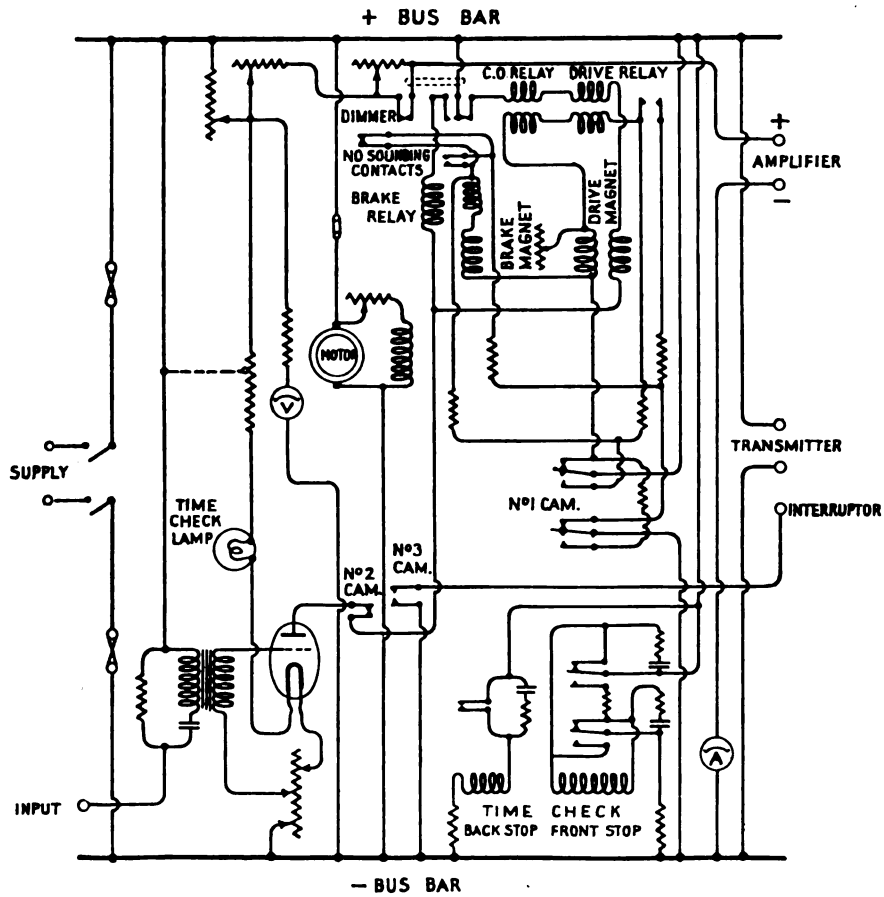

FIG. 4.

The pointer itself is held to the spindle in a similar manner. The position of rest of the pointer is adjustable by means of a screw knob on the right side of the indicator case. This is necessary because the sounding is actually measured from the face of the projector, which is in the bottom of the ship, and the pointer must be set so that it starts from a position on the scale corresponding to the depth of the projector below water—that is to say, the draught of the ship.

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The pointer spindle also carries a toggle arm which bears against and closes a pair of contacts when the pointer has travelled to the full extent of the scale. These contacts, called the No Sounding contacts, are in parallel with the contacts of the brake relay. When they close the pointer is captured from the drive magnet and held locked at No Sounding, thus indicating that no depth has been measured, and at the same time protecting the pointer mechanism from injury.

Check on Speed of Rotation.

It is obviously necessary that the flywheel should be running at the correct speed. A look-out is kept on this point by a device known as the time check, which operates as follows :—

It consists of a disc having at its centre an axle running in agate bearings, which is kept turned in one direction against a magnetic back stop by the action of a spiral spring. There is a projecting spring leaf on this disc, which is struck a light blow by a projection on the flywheel once in each revolution. This light blow drives the disc round on to another stop, which is also magnetic. This magnetic front stop catches and holds on to a pallett on the disc until such time as the projection on the flywheel reaches a set of contacts which break the circuit through the front stop magnet windings and also demagnetise it by reverse current. At this moment the time check disc is released and the spiral spring on the time check causes its disc to return to the back stop. There is a small hole pierced in the time check disc and there is a window in the edge of the flywheel and another in the scale plate. When these three are in line a ray of light from a small lamp can shine through them all. This lamp is in series with the indicator valve and acts as a telltale for its filament. The time taken for the time check disc to turn far enough from the front stop to bring its hole up into line with the ray of light is sufficiently nearly constant, and if the flywheel is moving at the right speed it will bring its window into line with the ray of light at the same moment as the hole in the time check disc passes across it. In other words, if the flywheel is going at the correct speed the same time will elapse between its projecting striker operating the demagnetising contacts of the time check front stop and its window coming into the ray of light, as elapses between the front stop being demagnetised and the hole in the time check disc coming into the ray of light.

The window in the flywheel is very wide, and its leading and trailing edges are filled in with red and green celluloid, so that if the flywheel is going too fast the ray of light will shine through the red portion of the window and the flash will be red ; if the flywheel is going too slow the flash will be green. The clear centre of the window is so narrow that if the flywheel is making half of a revolution too many per minute there will be a tinge of colour in the flash, and the coloured parts of the window are wide enough to show a flash of the appropriate colour if the flywheel speed is six revolutions per minute wrong.

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In order to avoid useless mechanical shock, the circuit of the time check back stop is broken just before the projection on the flywheel strikes the spring leaf, the contacts being actuated by a special wedge on the edge of the flywheel.

All the contacts controlling the time check stops (three sets in all) are provided with anti-sparking shunts and condensers. The time check stops are mounted on resilient seatings so as to reduce the noise and shock.

The two arms which carry the time check stops can be moved round their axis, so as to adjust the violence with which the spring leaf on the disc is struck. It is clamped in place at one central and one other point. The blow should only just be sufficient to drive the disc round to the front stop.

The pull of the time check spiral spring can be adjusted by turning a knurled washer carrying the anchor pin for the outer end of the spring. This washer is held by friction washers and will remain wherever it is put.

This disc permits the whole time check mechanism to be adjusted so that the flash will be white when the flywheel is running 68 revolutions per minute.

Operation of Cams.

The set of repeating cams operate as follows. No 1 cam is called the de-mag cam and it operates what is in effect a two-pole two-throw switch. When the cam rollers are riding on the high part of the cam the contacts are made so as to bring the magnet and relay circuits into action at the working polarity. When the cam rollers slip down to an intermediate level the circuits are opened, and as the cam rollers pass over the low level the circuits are momentarily closed at the reverse polarity. A separate set of resistances are used for the " de-mag " current so as to permit of compensation for any variations in the samples of iron in use.

No. 2 cam completes the H.T. circuit of the indicator valve, and opens it again after about 1½ seconds.

No. 3 cam operates the sounding contacts, which are closed at the moment when the sounding is required, and remain closed for about one second.

The setting of the cams is such that the " de-mag " cam contacts close to the working polarity, and the H.T. circuit to the indicator valve is completed at the same moment. The sounding contacts close immediately after.

Minor Controls. Volts Control.

As stated above, the whole outfit is adjusted to work correctly at 105 (or 210) volts, and a rheostat is provided so as to adjust the mains or battery volts available to this figure. This handle is at the left hand lower corner of the indicator, with a voltmeter immediately above it.

There is a tell-tale ammeter which shows the total amplifier current. This should be 0.41 at " bright." There is a semi-permanent resistance in series with the

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amplifier to allow of this figure being corrected. If the filament of the P.240 valve in the amplifier has failed, the ammeter will read about 0.25. If the rectifier filament has failed the ammeter will read 0.3 about. If one or other of the S.215 filaments have failed the ammeter will also read about 0.25.

The dimmer resistance which is used to deaden the amplifier during the shock of emission is in series with the amplifier resistance. It is short circuited by the dimmer contacts of the change over relay at the moment when the latter changes over from drive to brake. When in circuit the dimmer resistance should reduce the amplifier current from 0.41 to 0.36 or 0.37.

Time Check Control.

This is simply a field regulator for the motor, and is used to regulate the motor speed in accordance with information given by the colour of the time check flash. If the indicator has been standing for a long time in cold weather it is sometimes necessary to turn the time check control handle as far as it will go to the right before the motor will start.

Main Switch and Fuses.

The mains are brought directly into the terminal board in the back of the indicator case, thence to a double pole switch worked by push buttons in the face of the indicator, thence to a pair of fuses, and thence to distribution bus-bars.

There is a link in the main motor circuit, which can be taken out if it is desired to test the indicator without running the motor.

Indicator Valve Circuit.

The filament is heated directly from the mains through a suitable fixed resistance. The time check lamp is in this circuit immediately on the positive side of the valve filament, and there is an adjustable resistance between the negative side of the filament and the negative bus-bar. The grid connection is taken to a slider on this resistance so as to apply a suitable bias to the grid.

The Marconi Sounding Apparatus is now installed in several trawlers, and is giving a valuable service. Even under the very severe conditions of trawler working the installations are keeping up to the level of performance required, which is " two accurate soundings per minute." The apparatus is designed to operate four times per minute and even under very bad conditions accurate soundings are obtained on average twice a minute, the remaining indications being " No Sounding."

There are occasions when the indicator shows a *false* sounding, but these are isolated and very few in number. They can easily be recognised by their wide departure from the probable depth and are in no way misleading.

J. A. SLEE.

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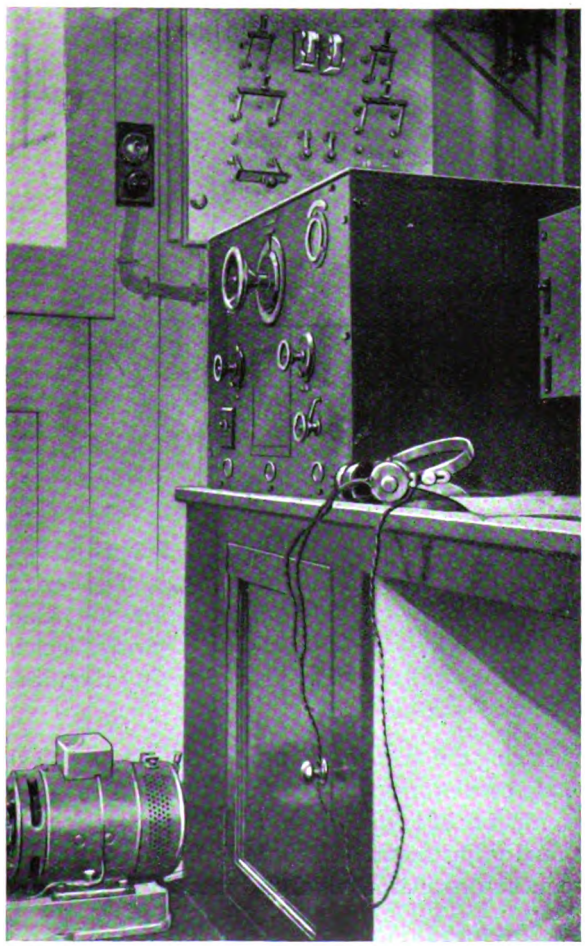
A LOW POWER NAVAL TRANSMITTER

TYPE T.N.5A

The demand for low power transmitters suitable for installation on tugs, naval pickets and motor boats is rapidly increasing and in connection with this the Marconi Company has developed a small transmitter, known as the T.N.5A, which can also be used as an auxiliary set on larger vessels.

THE type T.N.5A transmitter is designed for signalling by telegraphy only either on the I.C.W. or C.W. systems. A photograph of the transmitter installed in a naval tug is shown and the simplicity and compactness of the design will be apparent. All the controls are mounted on the front of the transmitter, including a power regulating control, and the component parts are fitted in a rigid iron framework and enclosed by protecting panels.



The transmitter is designed to cover a wave range of from 400 to 1,200 metres, and the working range over sea under ordinary conditions when using full power is of the order of 100 nautical miles.

The transmitter is nominally rated as a 200 watt set, this being the approximate power supplied by the H.T. D.C. generator which is used for supplying the voltage to the anodes of the valves. The standard motor generator supplied with the set delivers a high tension voltage of 800-1,500 volts at 150 m/a, and a low tension voltage of 8-12 volts at 12 amperes.

Alteration of power is

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accomplished by increasing or reducing the H.T. voltage and, if necessary, by altering the coupling between the closed circuit and aerial circuit. 2 type M.T.11 valves are used in the transmitter.

Technical Description.

A wiring diagram of the set is given in Fig. 1 and the circuit will be seen to consist of a high frequency oscillator and low frequency modulator for I.C.W.

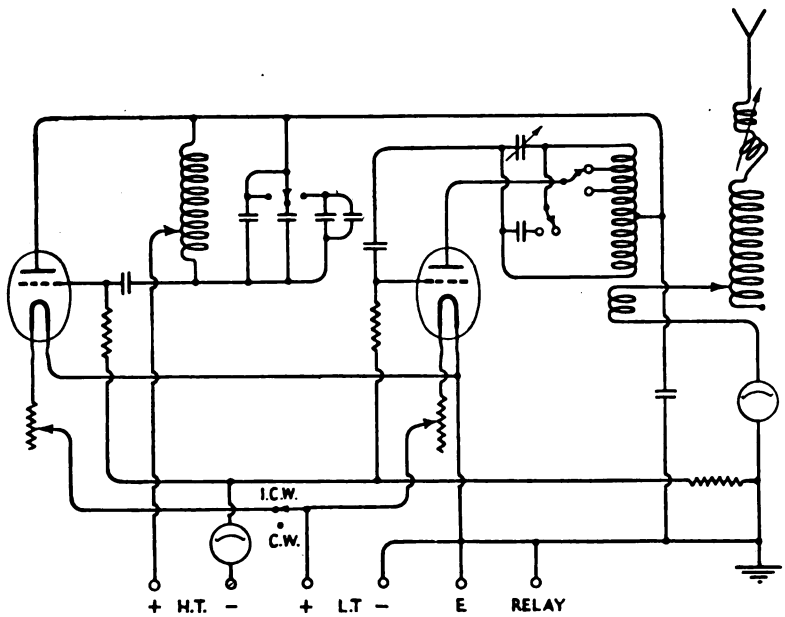

FIG. 1.

signalling. The high frequency valve is fed through a portion of the low frequency tuning inductance and the H.T. supply to the anode of the high frequency oscillator is thus modulated at audio frequency. A choice of 3 notes is provided on the audio frequency oscillator, and the required note may be selected by a switch which connects one of three condensers across the oscillating circuit. Normally the three notes provided are 600, 900 and 1,200 cycles per second.

In the case of continuous wave working the filament of the modulator is switched off and the feed to the high frequency oscillator is then unmodulated. The aerial tuning inductance is provided with a number of tapping points for coarse wavelength adjustment, and a variometer for final adjustment. The aerial circuit is coupled to the closed circuit of the high frequency oscillator which is tuned by means of a variable condenser.

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Keying is accomplished by inserting a high resistance in the common lead from the filaments which are earthed to the grids of the two valves and the negative high tension. A relay is provided for this purpose and contacts for " listening through " are also mounted on this relay and switch the aerial from the transmitter to the receiver during " space " periods.

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INFLUENCE OF BEAM AERIAL HEIGHT ON SIGNAL INTENSITY

With the increasing use of the Marconi type of Beam Aerial array, the question often arises as to the probable improvement which would result as the height of the aerials in the array were increased.

As an illustration of what might be expected, a case is given below which considers the effect of increasing the height of each aerial from 1λ *to* 2½λ.

IN order to obtain an estimate of the maximum gain that could accrue from using large heights of aerial, the following ideal case may be considered, after which the modifications necessitated by practical requirements can be taken into account.

Consider an array of aerials of n_1 wavelengths horizontal aperture and n_2 vertical aperture isolated in space, and let the receiver be on the line perpendicular to the plane of the array Fig. 1. Then in the limit when n_1 and n_2 are large the amount of power necessary to produce a given signal is inversely proportional to $n_1 n_2$. It therefore follows that in comparing the performance of any two arrays it is the areas of the two that must be compared. A reduction in breadth of the array could be compensated for by an equivalent increase in height.

In this ideal case the gain is occasioned by the fact that all the component parts of the array, whether arranged vertically or horizontally, conspire to produce radiation in the direction OR, and cancel to a greater or less extent by phase opposition in directions other than OR.

A theoretical and experimental check, with regard to the effect of increasing height, on this result has been published in I.E.E. Proceedings* in which an aerial ¼λ high was compared with one ½λ high; the theoretical magnification is 1·7 and the observed value 1·6. The approximate theoretical curve is shown in the Fig. 4, in which it appears that the gain of a full wave over half wave uniform aerial is 2/1.

To obtain the whole benefit of the concentration by increasing n_2, the vertical height, the whole of the energy must be transmitted along OR.

In any actual case we know, chiefly from various impulse and facsimile measurements, that the energy proceeds from the transmitter to receiver by a series of ricochets between the earth and Heaviside layer. This is illustrated in Fig. 2.

---

*"Design of Transmitting Aerials for Broadcast Stations."

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The whole energy is by no means carried along the ray OR. The useful rays form a sheaf in the vertical plane containing transmitter and receiver. The magnification in the vertical plane depends on the angular opening θ of this sheaf of rays Fig. 3. Thus, if they deviate but little from the horizontal direction OR practically the full magnification will be obtained. The vertical magnification of the beam depends upon the mode of transmission. This depends on wavelength, distance, etc.

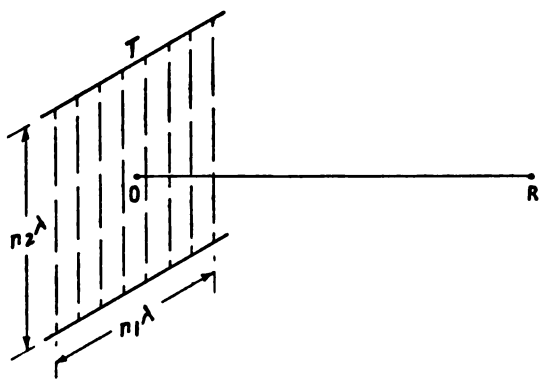

FIG. 1.

Experiments made with a view to determining the angular width of the sheaf of rays by balancing a frame and vertical aerial, which are described in the writer's "Short Wave Wireless Telegraphy," I.E.E. Journal, June, 1927, p. 607, show that for distances of 2,000 km. and more the rays which carry the main energy are confined to a sheaf with a small angle of elevation, i.e., not greater than 20°. For this deviation from the horizontal (if the direction of propagation of the aerial is slightly elevated) the directive efficiency in the vertical plane is near its ideal value, so that the gain of a 2λ to 2·5λ height aerial over one of $h=\frac{1}{2}\lambda$ is approximately 2 to 2·5 to 1.

Experiments prove therefore that in the majority of cases of medium and long distance transmission the gain of raising the height of the aerial will be nearly in proportion to the height of the aerial, that is for heights of $\frac{1}{4}\lambda$ and more.

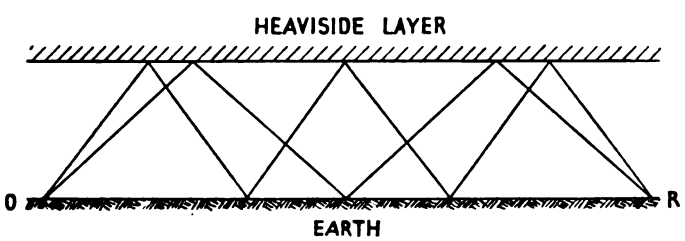

FIG. 2.

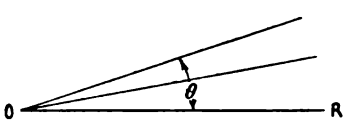

FIG. 3.

Evidence that the gain on raising the height of the aerial is close to its theoretical value is published in a pamphlet of Bell Laboratories on "Short Wave Transatlantic Radio Telephony," where measurements are quoted giving the gain on raising the height of the aerial. Indirect experiments showing the same effect are published in the writer's paper "An Investigation of Short Waves," where it is shown, p. 998,

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that the E.M.F.'s on two half wavelength aerials stacked vertically are practically equal and additive in phase, thus proving that the main energy of long and medium distance circuits is transmitted along nearly horizontal rays, for which the magnification on raising the aerial vertically approaches its theoretical value.

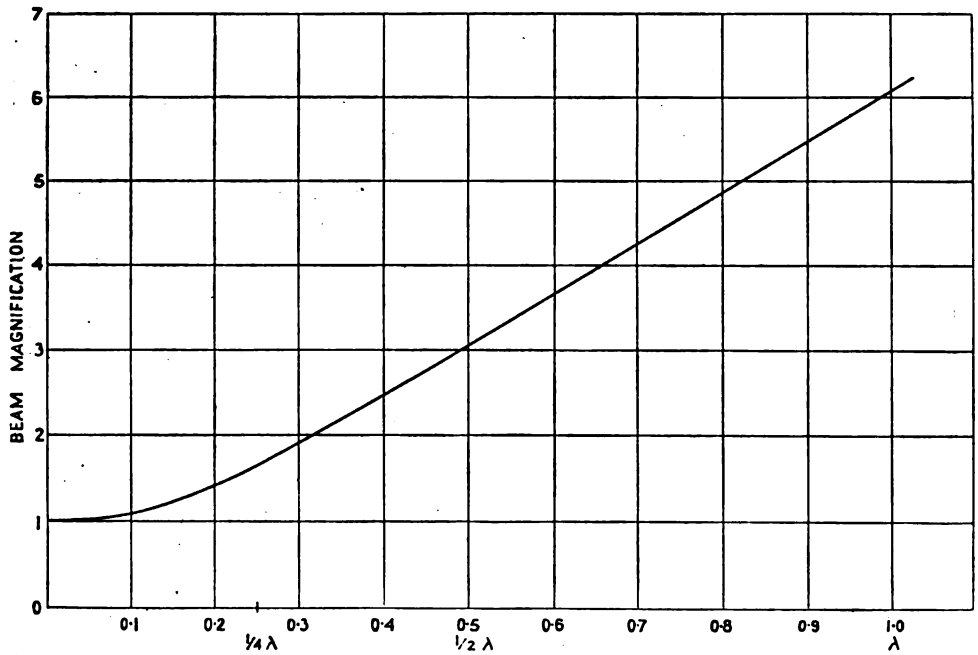

FIG. 4.

In spite of this high angle radiation may be present on the 24 to 29 metre from time to time, but for high speed working it is an advantage to cut out the higher angle rays (by using the vertical directivity of the high aerial) even at the expense of some magnification. The reason for this is that the higher angle rays are delayed and tend to broaden the morse dots, and make such a heavy marking bias that high speed is impossible. For example, a ray at an angle of 60° will arrive $\frac{d}{c}\left(\frac{1}{\cos. 60°} - 1\right)$ sec. later than the direct signal (where d is the range), *i.e.*, 6·6 milliseconds, which would spoil working at 150 w.p.m., and probably limit the speeds to less than 100 w.p.m. Such a disturbing ray at 60° would be very largely reduced by using an aerial 2λ to 2½λ high.

As an example, we may state that the theoretical gain of an aerial of 2λ aperture and from 2 to 2½λ high over a single ½λ doublet will be approximately from 4π to 5π, *i.e.*, 12·56 to 15·2, but the theoretical maximum gain will probably only be reached in exceptional cases. T. L. ECKERSLEY.

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THE MARCONI MARINE RECEIVER

TYPE 352

In order that a marine receiver shall be of the greatest service, two points have to be carefully considered :—

1. *It must be compact.*
2. *It must be simple in operation.*

In view of the extended waverange on which marine communication is now carried out, the Marine Receiver type 352 has been designed, together with a note filter which is of great use in separating the desired signal from others not desired, particularly at the longer wavelengths, and a separate heterodyne oscillator for reception of C.W. transmission.

The complete equipment to be described below consists of a two-valve receiver, type 352, a separate heterodyne type 357, and a note filter type 358. The receiver is capable of reception on all wavelengths from 15 metres to 20,000 metres, and the separate heterodyne possesses a wavelength range of from 200 to 22,000 metres.

THE receiver type 352 employs two valves, one as an oscillating detector and one as a low frequency amplifier. A diagram of connections is given in Fig. 1. Either 2, 4 or 6-volt valves can be utilised as desired, although a 2-volt supply is recommended. The high tension voltage should be of the order of 72 volts.

Tuning is carried out by means of a set of induction coils and a variable condenser. On the short waves, i.e., from 15 to 200 metres, special plug-in inductances are employed, fixed inductance coils being used for the longer waves, the correct coil being selected by means of a switch.

The tuning condenser consists of two parts, one part having a maximum value of .001 mfd. and the other a value of ·00015 mfd.

The moving plates of both the parts are connected to the rotating spindle which is earthed. The fixed plates of both parts are connected by way of a special switch to the grid of the detector valve, the appropriate set of fixed plates being connected for either long or short waves.

Reaction control is obtained by means of a variable condenser connected between the plate of the detector valve and a reaction coil, coupled to the grid circuit of the detector valve.

The detector valve output is coupled to the low frequency valve by an L.F. transformer. Low resistance telephones must be employed, a suitable telephone transformer being incorporated in the set, and across the secondary of this trans-

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former is connected a high resistance connected as a potentiometer, which provides an effective means of varying the volume of the output.

A three-electrode or pentode valve can be used as the low frequency amplifying valve, a pentode valve being employed only when the service necessitates increased amplification. Normally the output from a triode will suffice, the amplification obtained being enough for ship board requirements. A rejector circuit is incorporated in the aerial circuit, and its function is to reduce interference on 600 and 1,000 metres. This circuit can be shorted by means of a switch when not required.

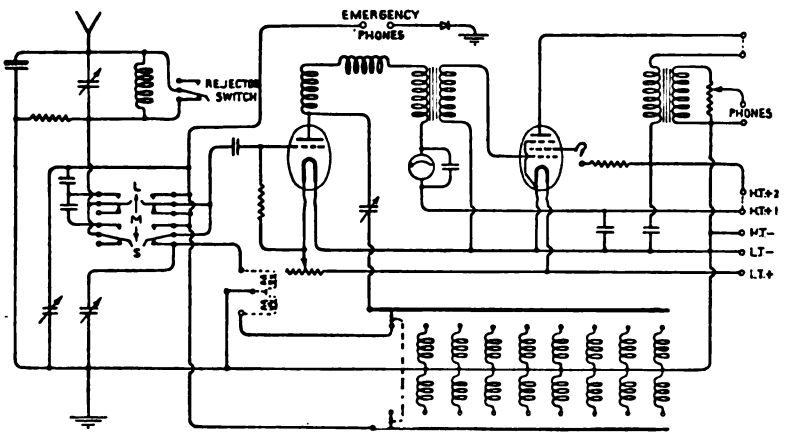

FIG. 1.

Two additional terminals are added to the receiver, and these permit the addition of a note filter, and are normally shorted by means of a link when the note filter is not in use. A milliammeter is connected in the plate circuit of the detector and indicates whether the detector is oscillating or not, and also determines if the detector valve has normal emission. A plug-in type of crystal is provided for emergency requirements.

Operation.

The operation and adjustment of this receiver will be found to be extremely simple. The valves are switched on by means of the " on/off " switch. The position of this switch is shown by an indicator in the small window on the face of the instrument.

The required waverange is selected by means of the multiple switch, or in the case of short waves by the correct plug-in coil. The aerial coupling switch is set to

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" S," " M " or " L," according as short, medium or long wave waves are to be received. It should be noted that in the " L " or long wave position the switch connects the grid of the detector valve and the .001 tuning condenser to the inductance switch unit, and also connects the .00015 condenser in series with the aerial and the grid of the detector valve.

In the " M " or medium wave position the connections of the .001 mfd. tuning condenser and the grid remain the same, but a further .00004 mfd. condenser is placed in series with the .0001 mfd. condenser in the aerial circuit. In the " M " position the signal strength will be reduced, but the selectivity increased. For short waves, when the switch is in position " S," the grid of the detector valve and the .00015 mfd. variable tuning condenser are connected to the valve holder. On short waves it will be noted that the aerial is not directly connected to the detector grid. Reception is made possible by means of the capacity existing in the switch.

Having placed the aerial coupling switch to a suitable setting, the tuning condenser should be set to the required wave. Next, adjust the reaction condenser until the receiver is in its most sensitive state and keeping the most sensitive adjustment, search for the desired station. The rejector circuit, which covers waves from approximately 300-1,200 metres, is brought into use by the rejector switch, and by manipulating the rejector condenser interference from broadcast or beacon stations can be greatly reduced. It should be noted that after the rejector has been brought into use it is desirable to slightly readjust the tuning and/or reaction condensers.

Adjustment of the L.T. resistance assists in obtaining smooth reaction free from threshold howl, particularly on the short waves. The volume control enables strong signals to be reduced in strength whilst maintaining tuning and reaction adjustments.

Crystal reception can be obtained when the crystal holder is plugged into sockets marked " crystal " and the telephones connected to the terminals marked " Emergency phones." The crystal contact should be adjusted for best results, and tuning adjustments may have to be modified slightly.

A diagram of connections of the receiver is given in Fig. 1.

Note Filter Type 358.

For the separation of long wave C.W. stations which cannot easily be obtained by high frequency selectivity, a note filter has been designed.

In principle the note filter depends upon the selection of a particular low frequency note, say of 1,000 cycles frequency, in preference to any other low frequency note.

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The method of obtaining the low frequency selectivity is by the use of three stages of low frequency transformers, the secondary of the transformer being tuned in each case to the required low frequency note.

The note filter may be tuned to accept any note from approximately 800 to 1,200 cycles.

The note filter is specially designed to be employed in connection with the type 352 receiver described above, and is suitable for working on either 2, 4 or 6-volt valves, the anode voltage being of the order of 72 volts.

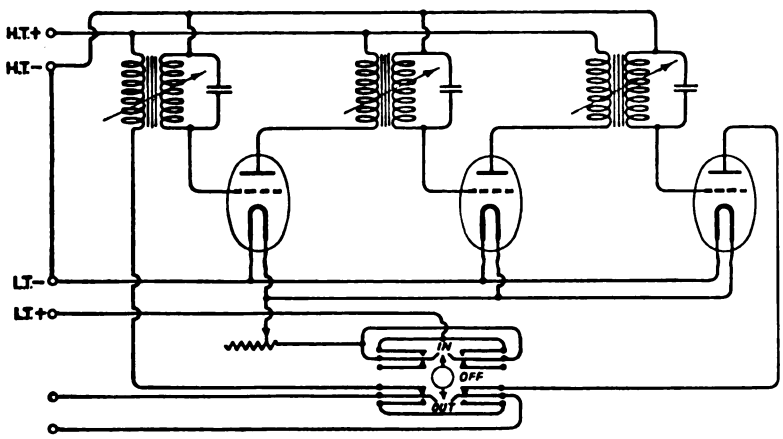

FIG. 2.

Technical Description.

The instrument consists of a front panel together with a base board upon which are mounted the component parts of the three-stage amplifier. The whole fits into a cast aluminium box and is designed to conform in general appearance to the receiver and separate heterodyne which will be described later.

The H.T. and L.T. terminals are on the right hand side of the box. There are no telephone terminals on the note filter as it is unnecessary to remove the telephones from their terminals on the receiver when the note filter is being employed.

A switch is mounted on the front panel of the note filter with three positions marked "in," "off" and "out." When the switch is in the position "in," the note filter follows the low frequency valve of the 352 receiver. In the position "off" the filaments of the valve of the note filter are disconnected from the low tension supply, but there is no through circuit from the receiver via the note filter to the telephones.

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In the position "out" the filaments of the valves of the note filter remain disconnected but a through circuit is arranged between the telephones and the receiver.

On the left hand side of the note filter is a filament rheostat which may be used for controlling the amount of amplification, and also the selectivity of the note filter.

The three tuned transformers have impregnated windings of comparatively low resistance together with an iron core choke which may be inserted at any desired distance in the transformer core. A suitable position for the core having been found it may be clamped by means of the three screws provided. The reason for using a variable core is to obtain sharply tuned transformers at the frequency of approximately 1,000 cycles without the use of expensive variable condensers of large

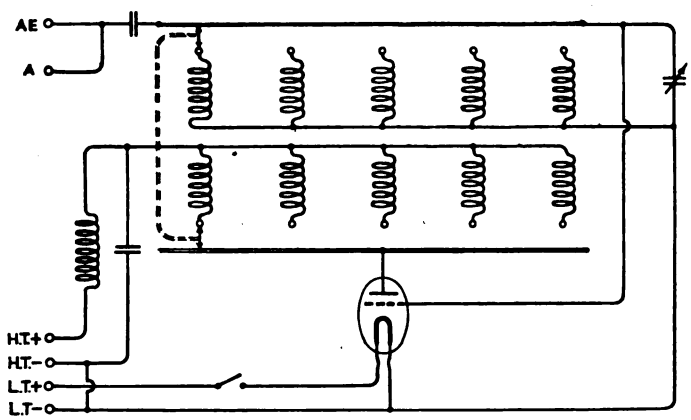

FIG. 3.

capacity. Each circuit may be tuned separately, but the best results are not always obtained until careful adjustments are carried out after approximate tuning has been performed on all three stages. To facilitate movement of the iron cores without disturbance to the valves or to any other part of the note filter, a nut is soldered on to the end of each moveable core. When adjusting the transformers a piece of the correct sized studding about 5 in. or 6 in. long may be inserted in these nuts and helps considerably the fine adjustment of the cores without disturbance of any other part of the note filter.

On the shorter wavelengths, particularly 400 or 500 metres, the note filter may not be found to be of very great help in separation of stations, due to instability on the part of the transmitting station, or of the local oscillator, but on the longer waves it should prove of very great assistance. A diagram of connections of the note filter is given in Fig. 2.

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Local Oscillator Type 357.

The separate heterodyne type 357 has been specially designed for use with the receiver type 352. The wave range is from 200 to 22,000 metres. This range is covered in five stages, a multiple switch selects the desired wave-band. Final adjustment of wave length is then obtained by a calibrated variable condenser. Calibration curves are supplied with each heterodyne.

A simple oscillatory circuit is employed, in such a manner that the required amount of energy, for best reception, is transferred to the receiver by means of a coupling capacity. This coupling capacity is located within the heterodyne.

A large high frequency choke is arranged, together with a decoupling condenser, to prevent any back coupling to the receiver via the battery or battery leads.

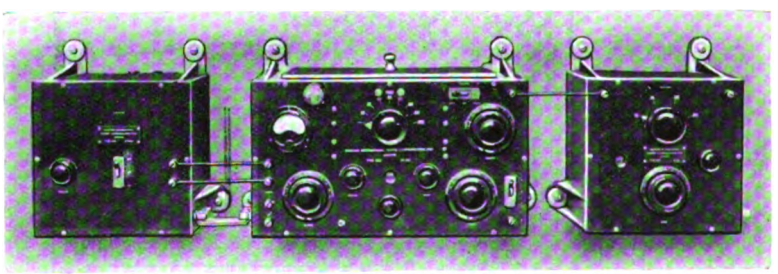

FIG. 4.

An on/off switch is provided so that the heterodyne may be switched off during the reception of spark or I.C.W. transmissions.

Technical Description.

The components of the separate heterodyne are mounted entirely on an aluminium panel, and the complete unit is fitted into a cast aluminium box.

The high tension and low tension terminals project through a slot in the right hand side of the box.

The wave range switch is situated in the upper portion of the box. This switch mounting is of robust construction and of sufficient size to carry the five sets of tuning and reaction coils. The control knob is situated at the top centre of the panel. A pointer attached to the knob indicates the location of the switch, and a device is incorporated in the switch to ensure definite contacts.

The tuning condenser is situated in the centre of the lower half of the panel immediately below the knob controlling the wave range switch.

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A shelf, mounted in front of the wave range switch, supports the valve holder and the anti-coupling choke.

The on/off switch is connected in the positive filament lead and fitted in the centre of the panel.

The separate heterodyne is for use on C.W. signals only.

A calibration chart is supplied with each heterodyne. This chart shows five curves corresponding to the five wave ranges on the wave range switch. To obtain any desired wavelength, it is necessary to ascertain first from the calibration chart the position for the wave range switch, and then set the condenser to the value shown on the curve to correspond to the desired wavelength.

The receiver may now be adjusted to the desired wavelength, and as soon as the required station has been tuned in, the filament switch of the heterodyne should be set to the " on " position. If all adjustments are now correct, a heterodyned note should be obtained in the telephones. The reaction condenser on the receiver must therefore be set back just below the oscillation point. A clear C.W. signal should now be heard, and the heterodyne condenser may be varied to give any note which the operator prefers for reading. There are two points on the scale a few degrees either side of the " blind spot " which give this note. Where interference is experienced at one point, the heterodyne should be adjusted to the alternative setting.

A careful readjustment of the reaction condenser on the receiver to a position just below the oscillation point, should now give a very considerable increase in signal strength.

A diagram of connections of the local oscillator type 352 are shown in Fig. 3, and a photograph of the complete installation showing the receiver type 352, the local oscillator type 357 and the note filter type 358, is given in Fig. 4.

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MARCONI NEWS AND NOTES

MARCHESE MARCONI'S WIRELESS TELEPHONE EXPERIMENTS

INTERVIEW BY WIRELESS

Photopress

Marchese and Marchesa Marconi on board the S.Y. " Elettra."

A NOVEL form of interview was held on April 30th last, when Marchese Marconi on board the S.Y. " Elettra " in the Mediterranean, was interviewed by Mr. Karl Bickel, President of the United Press of America, who was in New York, 4,400 miles away.

The customary form of interview, with questions and replies, was followed, Marchese Marconi speaking to New York through the new short wave telephone transmitter which was in the " Elettra "—described in the last issue of the MARCONI REVIEW. Mr. Karl Bickel was in a studio of the National Broadcasting Company in New York, and the conversation was broadcast throughout the United States of America by the National Broadcasting Company's chain of stations.

In the course of the interview, which was largely concerned with the subject of the international exchange of radio programmes as a means of promoting friendly relations throughout the world, Marchese Marconi said international broadcasting would certainly exert an important influence and should make the possibility of war more remote.

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Marchese Marconi, in reply to a question, informed Mr. Bickel that the power used to transmit his conversation from the yacht was taken from a storage battery and was only about 750 watts.

Mr. Bickel, who had already commented on the enormous distance over which the interview was being conducted, remarked : " That scarcely seems possible, does it ? "

In reply to a further question Marchese Marconi stated that he was using a wavelength of 26.7 metres.

Services of New Marconi Stations.

Discussing the reception of foreign programmes in America, Marchese Marconi said : " I am confident that the American public will not be disappointed in their expectations when they receive programmes from Italy. The first short-wave Italian broadcasting station near Rome is practically completed. Its official opening is now only a matter of days. The programmes will consist of music, concerts, opera, as well as descriptions of great Italian events and also, of course, speeches and lectures on a multiplicity of subjects which I have no doubt will be greatly appreciated by the large Italian-speaking and Italian-understanding population of the United States."

Mr. Bickel : " We understand that a short-wave transmitter is being erected for the use of the Vatican. Is it true that His Holiness will use this as a means of addressing the world ? "

Marchese Marconi : " Yes, you are right. A station is being put up under my direction in the State of the Vatican City, and I sincerely think His Holiness the Pope will use the radio as a means of addressing the world, but I am unable at present to state whether he will do so in the near future."

A conversation also took place between the Marchesa Marconi and Mr. David Sarnoff.

Perfect Results over 4,400 Miles.

Despite the distance of 4,400 miles over which the interview was conducted, perfect results were obtained, and at the close of the test an official of the National Broadcasting Company in offering felicitations to Marchese Marconi said : " We are very happy this came over so well. Signals are strong and static is low ; your transmitter is working perfectly. We wish to thank you and we will co-operate with you in any other test."

The National Broadcasting Company telegraphed to Marchese Marconi : " Programme remarkably well received. No fading, no static, fine strength and quality. Programme transmitted coast to coast and Canada through twenty-nine stations. Congratulations and thanks for your fine co-operation from us all."

The success of this interesting interview and broadcast is a further proof of the excellence of the new Marconi telephone equipment.

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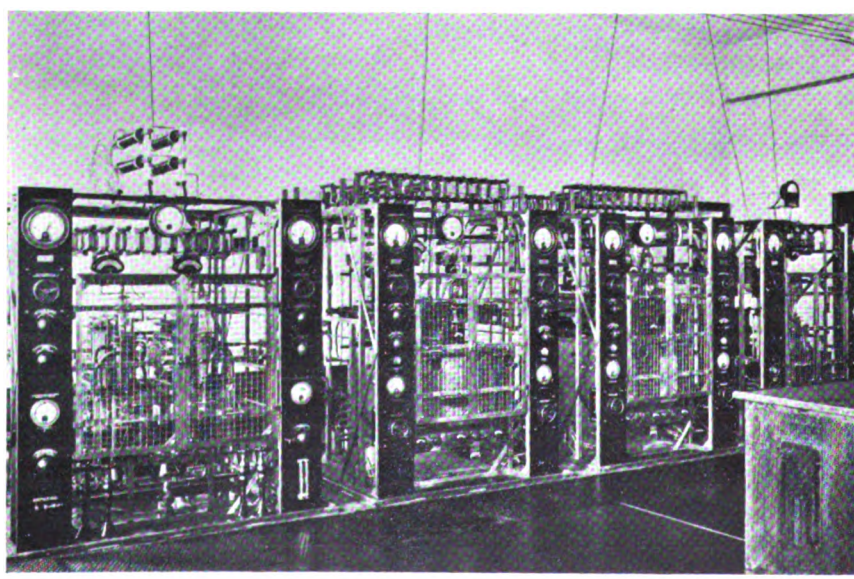
Italian Short Wave Broadcasting Station.

The experience of the Italian broadcasting authorities again demonstrates that the problems of short-wave broadcasting over long distances have been successfully solved by Marconi engineers.

The short wave broadcasting station near Rome which has just been completed by the Marconi Company for the Italian Broadcasting Company enables the Italian programmes to be heard in the Italian Colonies and in distant countries which are outside the range of the broadcasting stations operating on the normal wave band. The successful tests of the station on the wavelength of 25.4 metres were described in the MARCONI REVIEW No. 18.

Reports now received of the results obtained on the alternative wavelength of 80 metres show that on this wavelength the station is strongly and clearly received in the important Italian Colonies in Africa and distant countries abroad as well as throughout Italy.

Listeners in the Italian Colonies have reported that these transmissions are strong in intensity and very clear. Tributes to the quality of its performance have been received from Tripoli and Bengasi (North Africa), Rodi (Eastern Mediterranean), Asmara and Massoua (Erythrea) and Mogadiscio (Italian Somaliland), in which the descriptions " good," " clear and strong " have been unanimous. Among the reports



Transmitting panels of the Rome short-wave broadcasting station.

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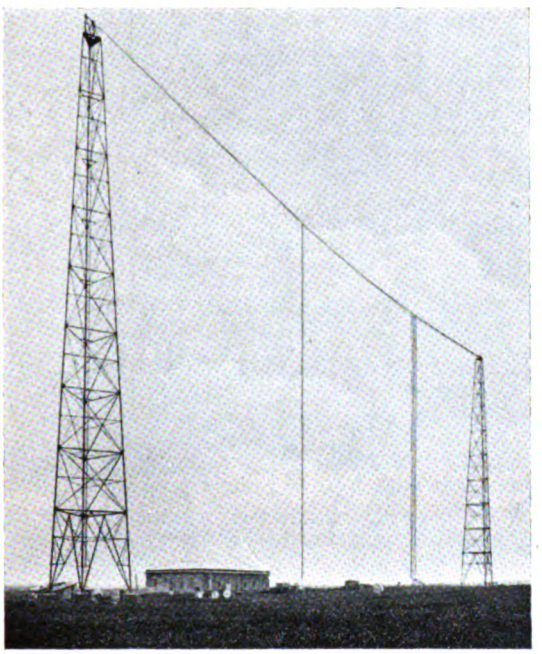
from foreign countries, a Peking (China) listener notes excellent and consistent reception.



Masts and Aerials of the Rome short-wave broadcasting station.

In Italy itself and neighbouring countries the short wave station is also well received on the wavelength of 80 metres, and reports from Genoa, Naples, Milan, Turin, Venice and Sicily indicate the reception of good signals. A listener in Turin remarks that not only was the modulation very good but also the intensity of the signals was equal to that of the 50-kilowatt long wave Rome station—a remarkable performance.

During previous tests on 25.4 metres the station was clearly heard in India, Australia, South Africa, and North America, listeners in these countries remarking on the stability and excellent quality, and the great strength of the Italian transmitter.

Mobile Wireless Stations.

A novel use of the mobility of wireless communication is to be made by the Egyptian State Telegraph Department, which has ordered from the Marconi Company three wireless sets mounted in motor lorries.

These stations will be maintained for use when and where required in areas not supplied by the land telegraph and telephone system, so that practically any point in a wide range of country on either side of the Nile can be linked up at short notice with the main Egyptian telegraph system.

The motor lorries, also of British manufacture, will be of the six-wheel type, fitted with caterpillar attachments so that they will be equally mobile on hard or soft desert country. Each lorry will carry a medium wave ½ kilowatt telegraph transmitter and a small portable short-wave transmitter of 100 watts power. The aerials will be suspended from 70 feet portable masts, and the wavelengths used will

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be between 600 and 2,150 metres on the medium wave set, and from 20 to 50 metres on the short-wave set. Self contained power plant will be provided.

Egypt is a country in which, apart from the Delta, the towns and cities with their connecting railway and telegraph communications lie along a narrow strip of land bordering the Nile, with large areas of sparsely inhabited and desert country on either side. In these circumstances the mobile wireless stations will be of particular value in providing special extension of the telegraph system either as a regular service or in times of emergency.

Short Wave Communication.

The remarkable performance of short-wave equipment under favourable conditions has stimulated special interest in short-wave communication.

The Marconi Company was a pioneer in the commercial utilisation of short-waves, and the new Marconi Type A.D.19 transmitter and A.D.20 receiver, operating over the wave band of 40 to 60 metres, have proved very successful both in tests and in commercial operation.

His Royal Highness Prince Purachatra of Siam, Minister of Commerce and Communications, who took two complete sets with him to Siam recently, has given us permission to make use of a report he made to us on their performance during the voyage from England.

Prince Purachatra states that he installed the A.D.19/20 equipment temporarily on the M.S. " Fiona " and that he was successful in communicating with Bangkok with C.W. telegraphy on 46.5 metres when the ship was in the Red Sea and the distance from Bangkok approximately 4,000 miles. From that time he remained in constant communication with Bangkok through this transmitter and receiver.

Wireless for Commercial Aviation.

The importance of wireless equipment for commercial aviation, and the supremacy of Marconi apparatus in this sphere, is further demonstrated by the recent decision of the Ad Astra Air Line, Switzerland, to equip its two new machines with Marconi transmitters and receivers. This follows quickly on an order recently received for four Marconi installations for the only other Swiss commercial air line, the Balair Company.

The equipment chosen for the new Swiss air liners is the popular Marconi A.D.6 Type combined transmitter and receiver, which is in daily use on civil, military and naval aircraft in practically every country in the world. The transmitter is of 150 watts power and the set may be used for telephone or telegraph communication.

Airmen Saved by Wireless.

Another instance of life saving by aircraft wireless is reported from Australia.

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Marconi short-wave Beam transmitter (above) and receiver (below) installed at the Aranjuez station, Madrid, for the Madrid-Rio de Janeiro telephone service.

On March 31st news was received that Mr. David Smith and Lieut. Shiers, who were attempting to fly from Sydney to England, were forced down in a desolate tract of the mid-Australian desert where the long distance aeroplane "Southern Cross" was lost last year. Fortunately, Mr. Smith and Lieut. Shiers had a wireless transmitter on board their machine which enabled them to issue an SOS message explaining their plight and asking for help. Land and air search parties were immediately organised and the airmen were rescued unharmed.

But for the aid of wireless their position would have been perilous in the extreme, for they were forced to land in a densely wooded hinterland surrounded by mountains and far from the nearest settlement.

Transatlantic Beam Telephone Service.

A Marconi Beam telephone service has now been opened to the public between Madrid and Rio de Janeiro. The first conversations took place between the Spanish Minister of Communications and leading officials in Brazil, all of whom expressed satisfaction with the quality of speech and the efficiency of the service.

The wireless stations conducting the new service in Spain

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are of the short-wave Beam type and were erected by Marconi's Wireless Telegraph Company at Aranjuez, near Madrid. In addition to the telephone service, a commercial telegraph service is in operation. For use in these circuits special receivers have been constructed by the Marconi engineers on behalf of Transradio Espanola, the Spanish Company to which these stations belong and which carries out the wireless services between Spain and other countries.

The South American end of the service is controlled by the Companhia Radio-telegraphica Brasileira.

Marconi High Speed Recorder.

The very high speeds of operation reached in modern telegraph services, such as those conducted by the Marconi Beam system, has given an added importance to time-saving devices in wireless telegraph offices. While on slow speed services an interruption of about a minute seemed of small importance, on Beam services operating at speeds of between 100 and 250 words per minute any stoppage, however short, has a more serious aspect.

The necessity for saving seconds has led to the introduction of a new Marconi high speed recorder, Type U.G.6A, which has been developed to eliminate the delay caused when a fresh roll of recording tape has to be brought into use.

The new recorder has two tape drawers, one for the tape in use and the other containing a spare roll of tape, which is so arranged that it can be brought into service immediately the running tape is exhausted. The empty tape drawer is then replenished while the recorder continues with the new supply of tape.

It has been said that progress in the technique of wireless communication lies as much in the improvement of detail as in the production of revolutionary designs, and the Marconi U.G.6A Recorder will strongly appeal to all those who are in charge of high-speed commercial telegraph services, as it eliminates delays which previously were unavoidable.

Interchange of Broadcasting Programmes.

In connection with the new Polish broadcasting scheme which was described in THE MARCONI REVIEW, No. 12, by means of which alternative programmes on the English model will be made available throughout Poland, it is interesting to learn that the contract obtained by Marconi's Wireless Telegraph Co., Ltd., includes the provision not only of six new broadcasting installations but also of very elaborate equipment of repeaters and correcting apparatus for landlines.

This apparatus will be installed to carry out important improvements in the scheme already in operation for the exchange of high-class broadcasting programmes between Warsaw and Berlin, Prague, Vienna and Budapest.

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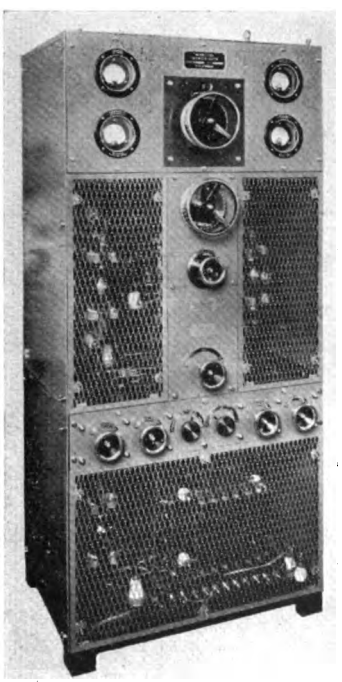
This international exchange of programmes between these five countries has come into existence, almost unobserved outside the countries concerned, as the result of the activities of the international commission for the exchange of broadcast programmes.

Under the scheme this group of cities broadcasts simultaneously at intervals a high-class musical programme, such as a Viennese opera or Philharmonic concert, provided by the members in rotation. Thus for each programme provided by one country it receives four programmes in return. By this means each country is able to spend more on its special programme than it would otherwise be able to do and each country receives better broadcast entertainment as the result.



Marconi short-wave naval transmitter Type T.N.4, rated at 500 watts.

Wilno and Lwow.

We have received from Poland a request to state that in the map of Europe showing the distribution of Marconi broadcasting stations which appeared on page 26 of the MARCONI REVIEW for March, 1930 (No. 18), two Polish towns which were mentioned in their English form as Vilna and Lemberg respectively are known in Poland as Wilno and Lwow.

Marconi Naval Apparatus.

Efficient wireless equipment is of the greatest importance to modern navies, and the following report of the excellent operation of Marconi naval apparatus under actual service conditions is therefore of particular interest.

The officer in charge of the wireless installation on a flotilla leader equipped with Marconi transmitters Type T.N. 2 and T.N. 4 and Marconi naval receivers has submitted the following report after carrying out long and exhaustive tests at sea :

"The communications have been very good and very regular, the wireless material meeting with the approval of everybody to such an extent that the Commander and the Lieutenant have nothing but praise for its working. I made a complete demonstration before the Commission of Inspection, tuning in rapidly on the waves they indicated, which I also did before a visiting Captain who went away from

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the ship so much interested both with the wireless and the goniometer that he could try it himself after a short explanation."

Naval Receivers and Direction Finders.

" As regards the receivers," continues the officer's report, " I may tell you that there is no limit to the distance, since they have not failed me at any time. News has been received daily from Nauen and Rugby, the Command being well informed of the world's happenings. In the report of communications drawn up by the Command I have seen the good impressions of the Commander with respect to the wireless material with which the ship is equipped."

Of the Marconi Naval Direction Finders on board, the report states that they were used for taking bearings up to 70 miles and gave determination of direction at 1,200 miles.

Island Telephone Service.

The British General Post Office has installed. a Marconi wireless telephone transmitter and receiver at the Hartland Point Coastguard station, North Devon, for communication between the mainland and Lundy Island.

Lundy is one of the numerous small islands off the West coast of Britain which, without the service of wireless, are completely out of touch with the mainland during long periods of foggy or stormy weather, the laying and maintenance of cables not being justified by the extent of the communications exchanged. Mr. M. C. Harman, the owner of Lundy Island, has installed a similar Marconi equipment on the island which is being operated in conjunction with the Hartland Point station.

The wireless stations, which take the place of a derelict cable, are to be used principally to enable aid to be sent to ships in distress off Lundy.

The apparatus employed on this service is the Marconi Type X.M.B.1a combined telephone transmitter and receiver of 100 watts power, which does not require skilled operation.

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THE MARCONI REVIEW

June, 1930

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THE MARCONI REVIEW

No. 21. *June, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

THE MARCONI-ADCOCK DIRECTION FINDER

Readings on the normal type of Direction Finder employing frame or loop aerials are subject to considerable inaccuracy owing to the prevalence of so-called "night effect."

The following article presents a short historical survey of "night effect," and describes investigations which finally resulted in the full understanding of the phenomena.

A brief description is given of a practical Direction Finder embodying the necessary requirements for accuracy under conditions of "night effect" and curves are shown comparing its performance with a standard Bellini-Tosi system.

The commercial design of the new Direction Finder, is well advanced, and a thoroughly practical instrument, simple in conception, and capable of an accuracy hitherto not possible will shortly be placed on the market.

AT the present time practically all commercial radio direction finding systems employ rotatable frame aerials or fixed loop aerials in conjunction with a goniometer.

During the daylight period, which is defined as that between one hour before sunrise and one hour before sunset, such direction finders give true bearings of high accuracy. Outside this period, however, grave discrepancies between the radio direction and the actual bearing of the transmitting station are possible owing to the existence of what is termed "night effect."

Stated briefly it may be said that the accurate functioning of direction finding systems employing loops or closed coils requires :—

(1) That the path of the radiation from the transmitting station lies on the great circle connecting the two points.

(2) That such radiation is normally polarised, *i.e.*, that the electric force is vertical and the magnetic field parallel to the earth's surface.

Investigators have proved that the first condition is always maintained on wavelengths above 100 m., but that the second requirement only exists during such time that the path between the transmitting station and D.F. receiver is

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entirely in daylight. During the other period the radiation, although following the great circle path between the two points, may arrive with any angle of polarisation and also at any angle of incidence with the earth's surface. Thus co-ordination between the action of the frame or loop aerial and the bearing of the transmitting station no longer exists.

Summarising, the frame or loop D.F. is an instrument whose indication is controlled by the degree of polarisation of the incoming radiation, combined with its direction of arrival. When this is entirely normally polarised, the indication coincides truly with the great circle path linking the transmitting and receiving stations, but if, as is the case during night periods, any abnormally polarised component exists in the radiation, the indication bears little or no relation to the true bearing of the transmitting station.

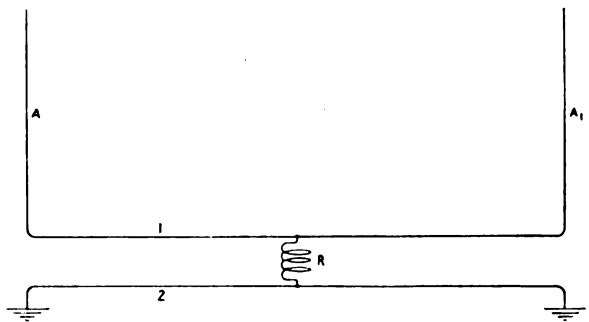

FIG. 1.

History.

The fact that the directional indication as recorded on loop or closed coil direction finders, was a function of polarisation of the radiation was simultaneously observed by Adcock and T. L. Eckersley by comparing the actual and apparent daylight bearings of aeroplanes transmitting with trailing aerials. The phenomenon was referred to as "aeroplane effect."

The outcome of Adcock's work was that in 1919 he filed a patent describing a direction finding system which theoretically was practically only receptive to the normally polarised component of the radiation, and which consequently overcame "aeroplane effect." Adcock, in his system, went back to the very earliest form of directive aerial arrangement, *i.e.*, simple vertical wires suitably spaced, as such aerials respond only to normally polarised radiation. The difficulty, which Adcock recognised, was that the horizontal lead necessary to convey the energy from these aerials to the goniometer would pick up any abnormally polarised component of the radiation and introduce error. The novelty of his invention was the arrangement of the horizontal lead in from each aerial in such a manner that any E.M.F. induced by the unwanted component was balanced out by virtue of the equal and opposite electrical configuration of this portion of the circuit. The scheme is shown in Fig. 1, in which A and A1 are the vertical aerials, R field coil of the goniometer and 1 and 2 the method of leading in the current from A to R.

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It will be seen that any E.M.F. induced directly in the horizontal combination will largely balance out. Obviously for an exact balance to be realised, the electrical

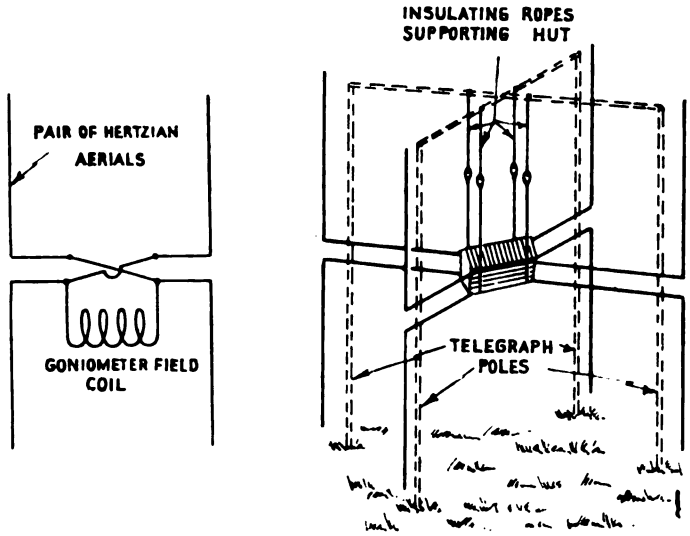

FIG. 2.

impedance of the earth connection must exactly balance that of the aerial, as this is the only condition in which the current distribution in the upper and lower horizontal limbs will be equal, and because this could not easily be obtained is probably one reason why the system did not immediately develop commercially.

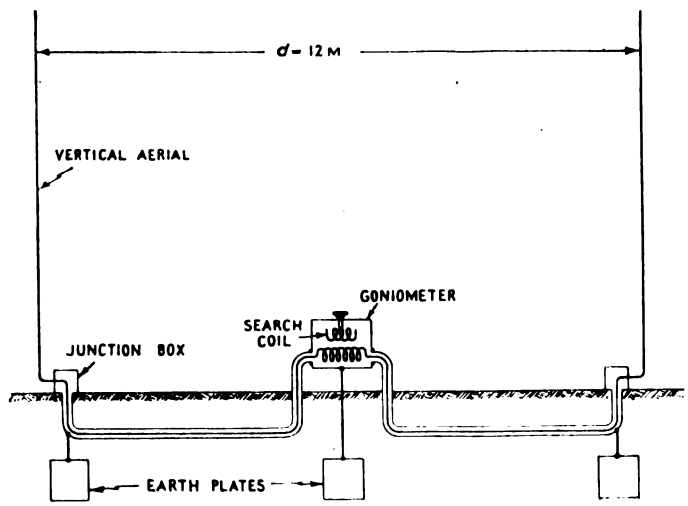

FIG. 3.

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T. L. Eckersley continued his own experiments and these culminated in a paper published in the " Radio Review," Vol. II., 1921, pp. 60-65 and 231-248, in which he definitely proved that night errors could be accounted for by the presence of an abnormally polarised component in the radiation. The only point that was not proved at this period was whether or not, in addition to the error introduced by abnormally polarised radiation, slight errors were present due to lateral deviation of the radiation from the great circle path.

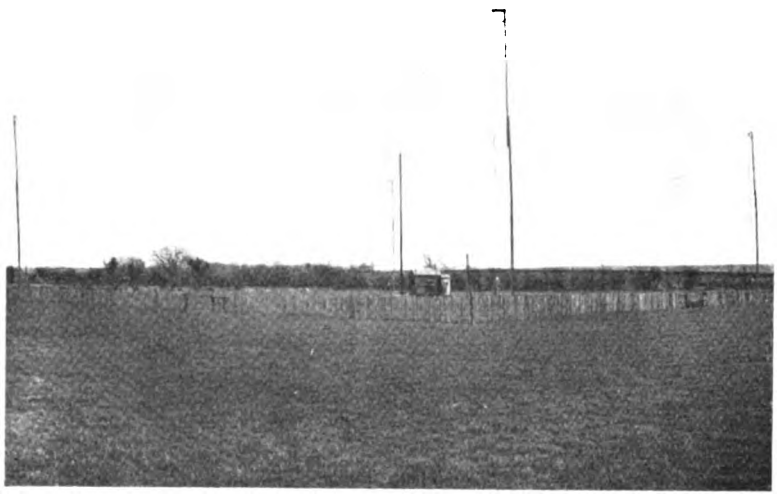

FIG. 4.

The following years were taken up in the development of accurate and simplified direction finding apparatus, the trend of which was largely governed by shipboard requirements, as although such a system as that suggested by Adcock was of great interest, it was recognised that it had no application to the most urgent and important field of direction finding, *i.e.*, the sea. The Marconi aperiodic loop system, together with the application of heart-shape reception for indicating the true sense of the signals was therefore commercially perfected and this system is still recognised as the most practical and accurate instrument for use at sea.

The Adcock idea, with the exception that it was utilised for obtaining experimental evidence of transmission phenomena, lay dormant until 1926, when Dr. Smith Rose and Barfield of the Radio Research Board gave particulars of an Adcock direction finder which was arranged in such a manner that it was practically immune

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from the reception of abnormally polarised radiation, and the results obtained confirmed that bearings of a very high order of accuracy were recorded under all conditions of day and night. This immunity was attained by arranging the Adcock aerial system in an absolutely symmetrical manner and entailed elevation of the receiving hut containing the goniometer. The arrangement as employed is illustrated in Fig. 2.

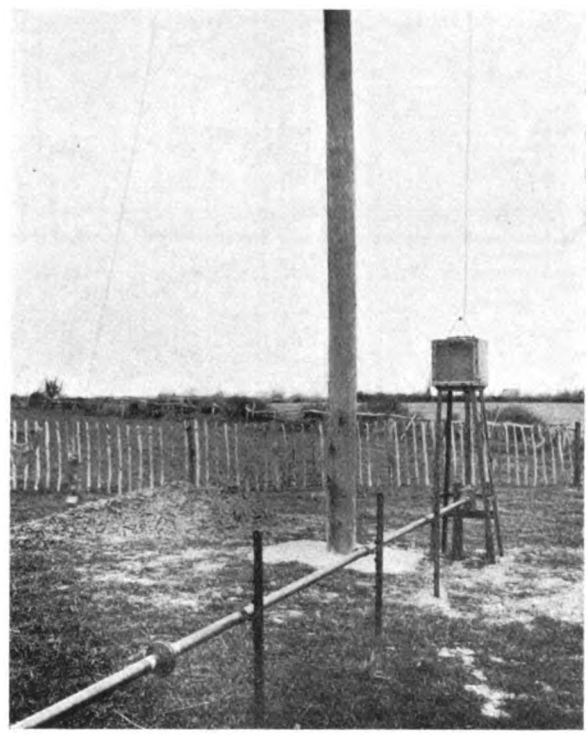

FIG. 5.

These experiments made one important contribution to already established knowledge of radio direction finding, namely that under normal conditions lateral deviation of the radiation from the great circle path was never recorded, and confirmed, that any direction finding system which eliminated the abnormally polarised component of the radiation would give true bearings during night periods. Unfortunately the elevated position of the hut rendered this arrangement impracticable from a commercial point of view and it is only quite recently that the system has been developed to a more practical form, in which the hut containing the radio-goniometer is situated at ground level.

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Recent Developments.

For the investigation of short wave transmission phenomena the Marconi Research Department developed a direction finder of the Adcock form, in which the

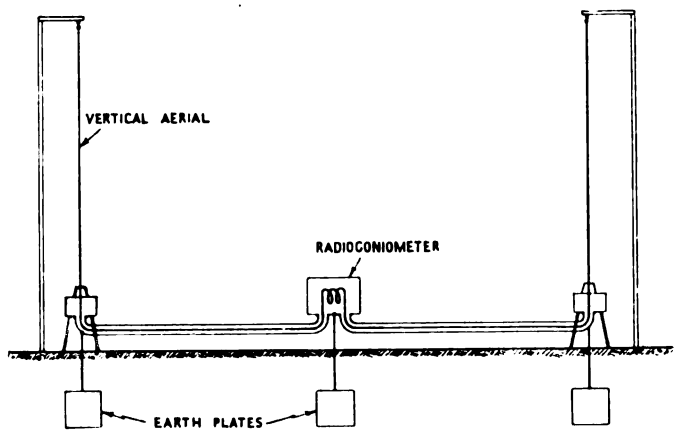

FIG. 6.

arrangement of the aerial system was on a thoroughly practical basis. A full description of the apparatus and results of the experiments were given by T. L.

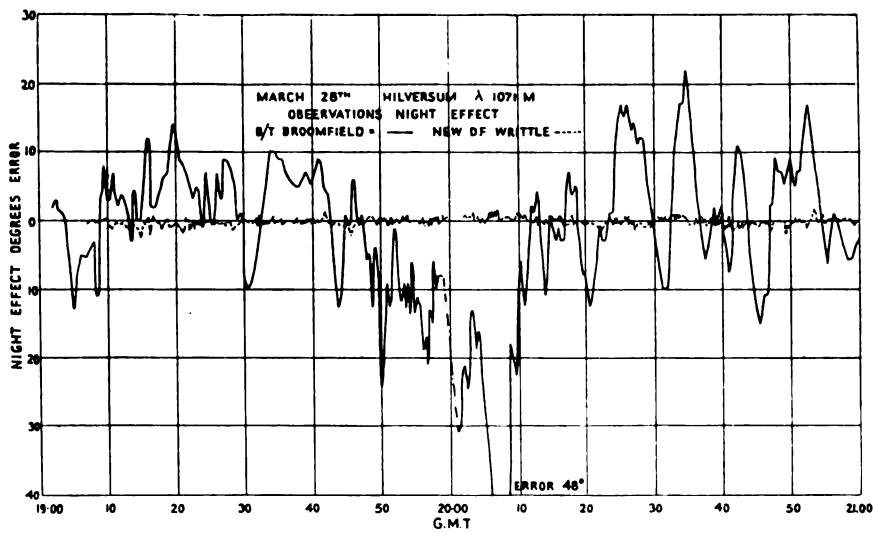

FIG. 7.

Eckersley before the I.E.E. in April, 1929. This modified Adcock system is illustrated in Fig. 3. It will be observed that instead of attempting to balance out any

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pick-up on the horizontal leads, these have been arranged in such a manner that they are to a very high degree non-radiating and therefore outside the influence of incoming electric waves.

Short wave radiation, except for very short distances, always has an abnormally polarised component, or in the nomenclature of practical direction finding, a permanent condition of night effect. This adaptation of the Adcock principle was

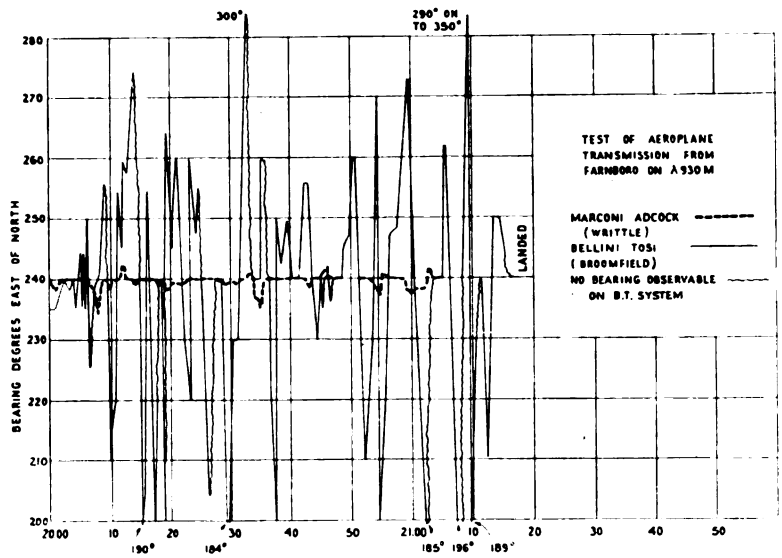

FIG. 8.

nevertheless so successful in indicating the incoming direction of short wave radiation that it was thought the same arrangement applied to direction finding on the medium wavelengths would result in a practical instrument which would be largely free from night effect errors. It was therefore decided to set up an experimental station and owing to the increasing importance of producing reliable direction finders as night navigation aids for aircraft, the operating wave band chosen was around 900 to 1,000 metres.

Four 70 ft. wooden masts were therefore erected at the corners of a square, the diagonals of which were 300 ft., corresponding to an approximate electrical separation between the aerials of one-tenth wavelength, or 36° on 1,000 m. Each of the aerials terminated in a screening box placed about 5 ft. above the ground, and in the same vertical line as the aerial. An electrical connection was made from each aerial to the goniometer, which was located in a hut central to the system, by means of a single conductor completely shielded in a copper tube and carried about 2 ft. above ground level. The reason for using copper tube feeder for these connections instead

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of buried cable was that with such an arrangement a much greater degree of electric symmetry can be attained, and this is important from the point of view of accurate direction finding. The goniometer was contained in the screening box, to which each feeder was terminated. The system was then earthed at the centre, and each feeder in the middle and also at the aerial end. In this manner the whole of the horizontal portion of the aerial system was rendered immune from the influence of any abnormally polarised component of the incoming radiation. A general view of the experimental station is given in Fig. 4, and the method of terminating at each vertical aerial in Fig. 5. Fig. 6 is a diagrammatic representation of one pair of aerials and their feeders and also illustrates the method of terminating these directly to the screening box containing the radiogoniometer. The latter was of standard form, close coupled, and designed for aperiodic working of the aerial system. The tuned search coil circuit was coupled to a very simple amplifier consisting of two screen grid high frequency stages, detector and double note magnifier.

Simultaneous observations were taken over a period on the Marconi-Adcock system and a standard Marconi Bellini-Tosi loop direction finder.

A graph combining a typical record is given in Fig. 7. The graph does not indicate in full measure the advantages of the new instrument as, in addition to the large error in the true bearing, which obtains with the Bellini-Tosi loop system during the night, there is very often considerable flatness for appreciable periods during which it is not possible to take bearings. This condition is not encountered on the Marconi-Adcock system and the readings, even under the worst conditions of night effect, are relatively sharp, and on wavelengths of the order of 1,000 metres it is possible to guarantee an accuracy of bearing of 2° to 3°.

This result is a very big advance in practical direction finding, and one which we are confident will meet the requirements of aiding aircraft at night. In this connection the graph of Fig. 8 is interesting. It represents a simultaneous record taken one hour after sunset of the position of an aeroplane transmitting with long trailing aerial on a wavelength of 930 m. from a distance of 60 miles. The aeroplane maintained its position to within a few degrees during the whole of the flight. As will be seen this fact was accurately recorded on the Marconi-Adcock system, while at the same time the record taken on the loop was, for all practical purposes, useless.

N. E. Davis.

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MARCONI MARINE SHORT WAVE RECEIVER

TYPE 372

The short wave receiver, type 372, described below, has been designed for use on board ship in the many cases where reception on waves of 14 to 100 metres is necessary.

The outstanding features of this receiver are simplicity and ease of control. An oscillating detector is employed where reception of C.W. is desired, and oscillation can be easily controlled by a condenser.

The set is very efficient and represents a considerable advance in short wave marine receiver design.

THE Marconi type 372 receiver is designed for ordinary marine short wave working over a waveband of 14 to 100 metres. As will be seen from the diagram of connections, Fig. 1, it employs three valves, namely, a screen grid valve between the oscillating detector valve and the aerial, in order to decrease to a minimum the amount of energy radiated from the receiving aerial when reception is taking place, a detector valve, and one note magnifying valve, having an output transformer in its anode suitable for use with low resistance telephones.

The receiver is arranged to work on 72 volts H.T. with a tapping of 48 volts for the screen grid of the screen grid valve.

Among the important features incorporated in this receiver are the method of wave-change by means of a switch, the use of anti-induction chokes in the battery leads, and a double condenser in the tuned anode circuit, in order to decrease noises to a minimum.

To aid reception, a milliammeter is inserted in the anode of the detector valve, while a voltmeter across the filament of the valves indicates when the filaments are being supplied with the correct voltage. The instrument is mounted on a rigid metal panel and a baseboard. All component parts of the instrument are attached to this panel and baseboard, and the whole of the receiver is housed in a strong metal case.

By unscrewing the screws on the edge of the front panel, the receiver may be entirely withdrawn from its case, thus rendering a detailed examination easy.

In order to assist in any change of valves or to permit a rapid inspection of the receiver, the top of the box is made in the form of a lid hinged at the back.

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The metal front of the receiver is covered with a black bakelite panel on which is engraved the function of each control knob.

Power Supply.

The receiver is designed to work on 2-volt valves of the following types :—

(*a*) Screen Grid Valve, S.215.

(*b*) Oscillating Detector Valve, H.L.210.

(*c*) L.F. Amplifier Valve, L.210, or Pentode Valve type P.T.235.

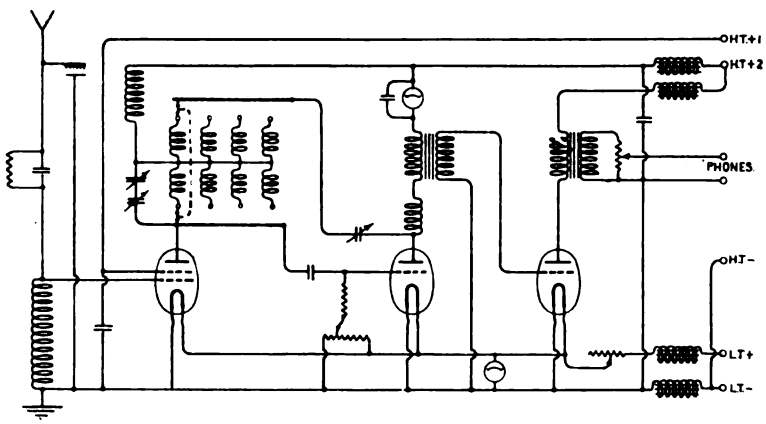

FIG. 1.

As will be noticed from the diagram of connections of this receiver, both the high tension and low tension supplies are taken through chokes embodied in the receiver. The resistance of these chokes on the low tension circuit is approximately 6 or 7 ohms, and hence the fall of voltage in these chokes prevents the use of a 2-volt battery when utilising 2-volt valves.

To overcome this difficulty, a filament rheostat has been incorporated in the positive side of the L.T. supply, between the positive L.T. supply and the valves, together with a voltmeter which is connected directly across the filaments of the valves.

In this manner, it is possible to make use of a 4-volt or 6-volt battery, whichever is more suitable for lighting the filaments of the 2-volt valves, the filament rheostat being utilised to maintain the filaments of the valves at 2-volts as indicated by the voltmeter.

The filament rheostat is arranged to be broken when turned full round to its "off" position, and therefore, in order to switch off the set and prevent unwanted consump-

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tion of current, it is only necessary to rotate the filament rheostat to the end of its travel in an anti clockwise direction.

It is permissible to use 4-volt or 6-volt valves of equivalent types to those cited above, but it will, of course, be necessary in this case to use 6-volt or 8-volt supply for the filaments of these valves.

Similar precautions to reduce induction interference, which may be picked up on battery leads, are taken with regard to the high tension supply, and in order to make full use of this arrangement, the negative high tension terminal and the negative low tension terminal should not be joined together external to the set, unless this is unavoidable.

In the case of the high tension chokes, the resistance is insufficient to cause a erious drop of voltage in the high tension supply, and therefore no adjustment is made in the high tension voltage to counteract the effect of the chokes.

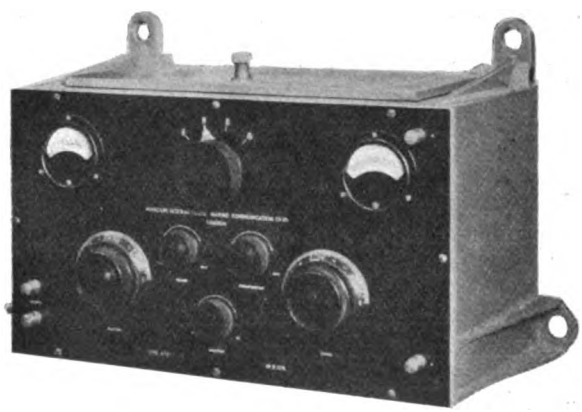

FIG. 2.

No choke is inserted in the screen grid high tension supply, but a condenser is placed across the screen grid to earth.

Aerial Circuit.

The aerial circuit consists of a simple semi-aperiodic arrangement. The aerial is connected direct to the terminal marked AE on the receiver, and from that terminal passes through the series condenser and the high frequency choke to the earth terminal marked E.

Across the series condenser in the aerial, is placed a static leak, to prevent accumulation of static charge on the aerial.

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In addition to this static leak, a spark gap is placed between the aerial terminal and the back of the earthed receiver panel. This spark gap will deal adequately with sudden heavy charges which may accumulate on the aerial during stormy weather, and which otherwise might cause repeated breakdown of the static leak.

The aerial side of the high frequency choke is connected directly to the grid of the screen grid valve.

No tuning of the aerial is attempted as signal strength from the main aerial of a ship is generally more than adequate for the requirements of short wave traffic, and it eliminates the necessity of utilising two tuning condensers, which is a serious obstruction to rapid searching under marine conditions.

Tuned Circuit.

The reception of C.W. signals on this short wave receiver is obtained by means of the well-known method of utilising an oscillating detector valve.

The oscillating circuit is placed in the anode of the screen grid valve and is connected to the grid of the detector valve by means of a grid condenser and grid leak. One end of the grid leak is connected to a potentiometer so that smooth reaction may be obtained on any wavelength within the range of the receiver, by selecting a suitable position on the potentiometer.

Reaction is obtained by means of a variable condenser coupled between the choke in the anode of the detector valve, and a reaction winding placed adjacent to the tuning inductance in the tuned circuit of the anode of the screened grid valve.

In the anode of the detector valve is inserted a low frequency transformer and a milliammeter. This latter enables reaction to be obtained and controlled with the smoothest possible adjustment, and is an important aid to the reception of signals under bad conditions.

In the anode of the screen grid valve, in addition to the tuned circuit, is inserted a small high frequency choke. The purpose of this choke is to enable very smooth reaction to be obtained.

It has been found desirable to utilise four stages of tuning to cover the wave-range of 14 metres to 100 metres. The first of these tuned stages covers a waverange of approximately 14 to 23 metres, the second approximately 20 to 40 metres, the third approximately 30 to 60 metres, and the fourth stage 50 to 100 metres approximately.

The difficulty of using plug-in coils has been overcome by means of a switch on which are mounted the tuning and reaction coils for the four stages.

Precautions have been taken with regard to the tuning condenser to prevent the possibility of noises creeping in during the process of tuning owing to slight variations

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of contact between the rotor and the fixed terminal to which the rotor is connected. To overcome this, two condensers are arranged in series. The rotors of the two condensers, both mechanically and electrically, form one unit. This rotor is insulated at both ends from the frame of the condenser. The two sets of fixed vanes are separately mounted on heavy insulation, and are entirely separate from one another.

By utilising this method of making the tuning condenser for short waves, it is possible to carry the wires from the inductance to two fixed points on the tuning condenser.

Experience shows that this method of connecting up a short wave tuning condenser gives extreme freedom from noise.

L.F. Circuit.

The rectified low frequency signal obtained in the anode of the detector valve is transferred by means of an L.F. transformer to the grid of the low frequency amplifying valve. As it is unnecessary in telegraphic work to consider the importance of quality, a grid bias battery is dispensed with, and the grid of the low frequency output valve is biased directly on the negative side of the valve.

In the anode of the L.F. amplifying valve is inserted a step down transformer, which is suitable for use in conjunction with low resistance telephones.

It will be noticed that the telephones are not connected directly across the secondary of this transformer, but via a potentiometer to the transformer.

The potentiometer serves as a volume control, and is extremely useful under conditions in which fading seriously upsets the sensitivity of the ear of the operator.

One side of the telephone is connected directly to earth so that there is no chance of the operator obtaining shocks through the breakdown of a telephone transformer.

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THE DIRECT CURRENT GRID METHOD OF MODULATION

The methods of amplitude modulation in common use may be broadly classified under two headings :—

(1) *Full power anode modulation.*

(2) *Power magnification of modulated grid input.*

The following article deals with a method which falls under the second heading. It is one in which modulation of the grid input is obtained by modulation of the grid bias.

The theoretical possibilities of the method are examined and the limitations experienced in practice are discussed and illustrated.

Comparisons are drawn between this and other methods of modulation.

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1. Introduction.

LIKE all other methods of amplitude modulation the Direct Current Grid Method aims at achieving a linear relationship between variations in the instantaneous value of audio frequency input voltage from a microphone source and the resulting variations in the instantaneous value of aerial current.

The method depends, fundamentally, on the fact that if the driving voltage impressed on the grid of a magnifier valve be maintained at a constant amplitude and the grid bias be varied in magnitude, then, ideally, the resulting variations of both the D.C. input to the valve anode and the efficiency of conversion to A.C. bear a linear relationship to the variations in grid bias.

It may be noted in passing that it follows from the last paragraph that the method is not applicable to a self-oscillator, but only to transmitters comprising a master-oscillator and one or more stages of magnification.

For varying the grid bias of the magnifier stage at audio-frequency the method employed in practice is to use the filament-anode impedance of a small triode as a grid leak which provides an automatic bias ; the required variations of this bias are obtained by impressing on the grid of the triode the output from a microphone, suitably amplified.

2. Basic Principle.

In order, however, to simplify the examination of the basic principle, as defined in the second paragraph, we will consider first the case of a magnifier stage in which grid bias is provided by a battery, and trace the relationship under ideal conditions, between the bias on the one hand and the D.C. input, efficiency of conversion to A.C. and aerial current on the other.

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We will take as an example the magnifier stage illustrated in Fig. 1, in which the anode potential V_B, is 2,500 volts and in which the driving voltage V_D impressed on its grid from the previous stage—a self-oscillator, O, in this case—has a constant amplitude of 600 volts peak. Grid bias is provided by the tapped battery G.B.

We will assume that the V_p I_p characteristics of the magnifier valve are as drawn in Fig. 2, from which it will be seen that at $V_p = 2{,}500$ I_p will be zero when $V_g = -150$. If, therefore, sufficient bias is provided by the battery G.B. to prevent the grid from becoming less negative than -150 volts at the positive peaks of the driving voltage V_D, there will be no D.C. input and consequently no A.C. output. This is one limit of the possible load excursion and may be denoted by a point, L_1 on the V_p I_p surface at $V_p = 2{,}500$, $I_p = 0$.

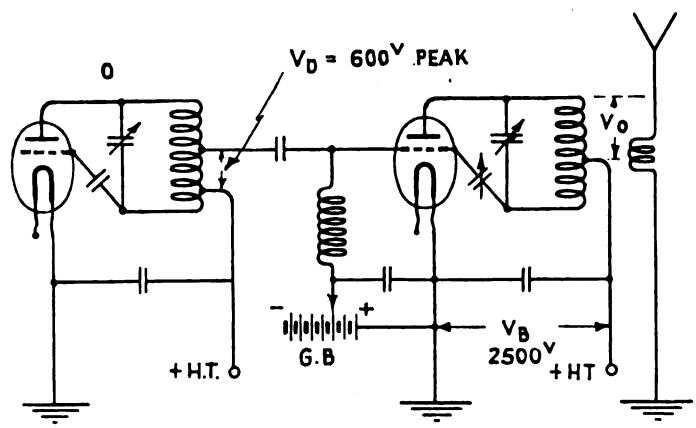

FIG. 1.

The other limit, ideally, of the possible load excursion is reached when the bias from the battery, G.B., is reduced to the point where the excursions of the grid, due to the positive peaks of the driving voltage V_D, give rise to a peak value of I_p which fulfills the following conditions :—

(1) is equal to the total emission of the magnifier valve ; or

(2) corresponds to an A.C. output such that the peak value of the A.C. voltage V_o across the output circuit is equal to V_B.

In practice, neither (1) nor(2) is entirely attainable, and for our example we will assume that the upper limit of the possible load excursion is reached when peak $V_o = 2{,}200$, and that this corresponds to a peak value of $I_p = 400$ m/a. The exact value of peak I_p will depend upon the ratio peak I_p/RMS I_p, the electrical constants of the circuit and the frequency.

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Since V_B and V_o are in opposition when I_p is at its peak value, we can plot I_p = 400 m/a, against $V_B - V_o$ = 300 volts on the I_p V_p surface, and this point, L_2, will represent the upper limit of the load excursion.

For intermediate values of V_o there would be corresponding proportionate RMS values of I_p. Since we are examining the process operating under ideal conditions we will assume for the moment that the ratio peak I_p/RMS I_p is constant, in which case the locus of the points of intersection, on the V_p I_p surface, of related values of peak V_o and peak I_p will be a straight line passing through the two points

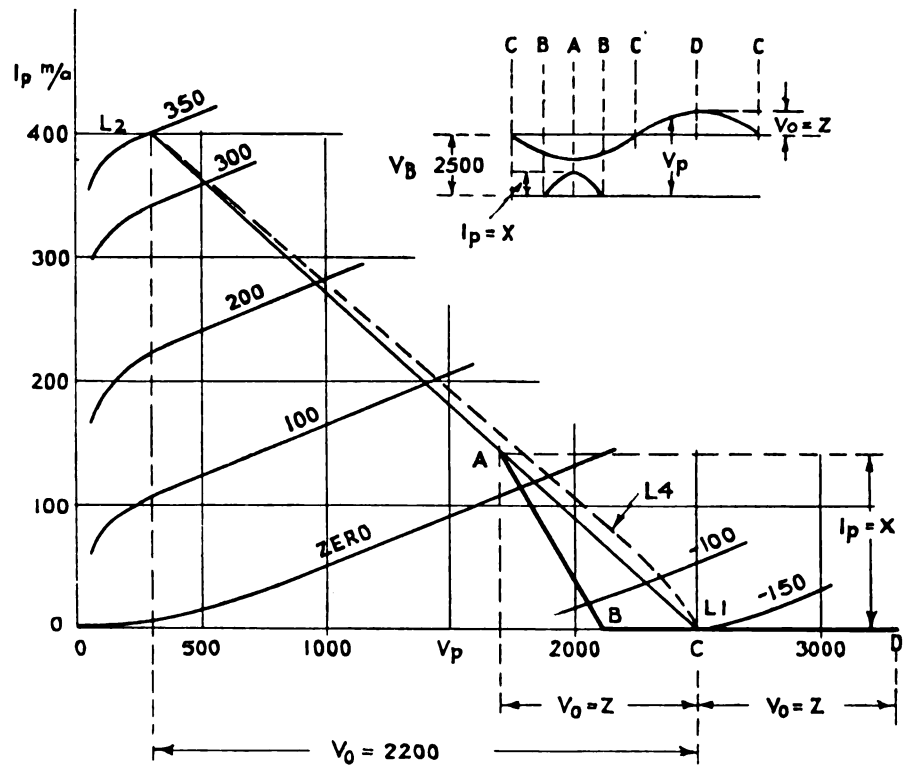

FIG. 2.

L_1 and L_2, representing respectively zero input and maximum input.

If this locus be transferred to the V_g I_p surface, Fig. 3, we can see clearly what bias would be required from the battery G.B., Fig. 1, to set the magnifier valve for any desired input.

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For instance, if the bias be adjusted to −750 volts, then the positive peaks of the driving voltage V_D will carry the grid only as far as −150 volts and there will be zero input. If the bias be adjusted to −250, then at the positive peaks of V_D the grid will swing to +350, which is the required grid excursion to give I_p = 400 m/a at V_p = 300 volts, *i.e.*, the condition for maximum practical input for the magnifier stage under consideration.

Therefore, by varying the voltage of the bias battery, G.B., from −750 to −250—the driving voltage remaining constant at 600 volts peak—we should carry the valve through every HF. operating condition from that corresponding to zero input and output to that for maximum input and output.

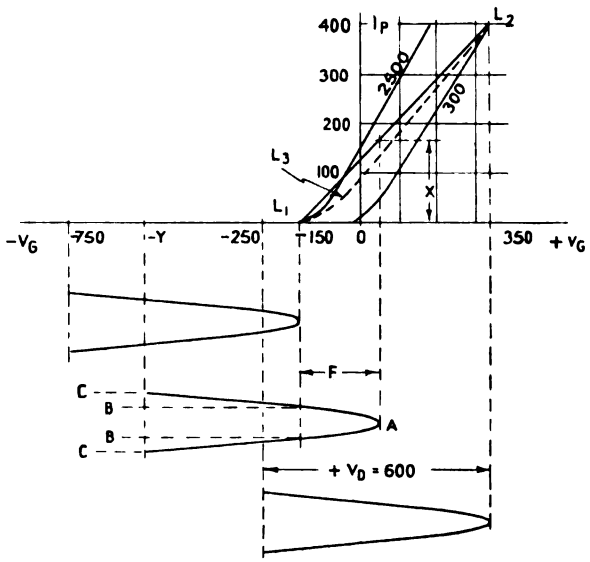

FIG. 3.

One such HF. operating condition is illustrated by the line ABCD, Fig. 2. It is that corresponding with a bias of −Y volts, Fig. 3, for which setting it will be seen that the positive peaks of V_D would carry the grid of the magnifier valve to (−150 + F) volts. The peak value of I_p would be X, which, from Fig. 2, can be seen to correspond with a peak value of V_o of Z volts. Anode current would flow during that fraction B.A.B. of the positive half cycle, C.A.C. of V_D, Fig. 3, in which the grid is more positive than −150 volts. A whole cycle of the HF. operating condition is shown on a time base in Fig. 2, and the line ABCD on the V_p I_p surface is its equivalent on that surface. The point A, which represents peak V_o and peak

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I_p for that particular operating condition, falls on the line L_1 L_2, which, as has previously been stated, is the locus of the points of intersection of related values of peak V_o and peak I_p.

Reverting now to the transference of this locus to the V_g I_p surface, Fig. 3, it is clear that it would remain a straight line, L_1 L_2, provided that there were no curvature of the valve characteristics. For the purpose of the argument we will assume for the moment that this is the case. That being so, it is obvious that peak I_p is proportional to variations in grid bias and therefore, also, is peak V_o.

Now, Output Power $= f_1 V_o \times f_2 I_p$, at resonance.

Where f_1 and f_2 are the ratios RMS/PEAK for V_o and I_p respectively, and under our assumed ideal conditions they will be constant ; as also will be the ratio average I_p/Peak I_p.

Therefore, Output Power = constant $\times$ (peak $V_o \times$ peak I_p)

Similarly, Input power $= V_B \times f_3$ peak I_p
where f_3 is the ratio average I_p/Peak I_p
$=$ constant $\times$ I_p,

and, therefore, is proportional to variations in grid bias.

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

and is thus proportional to peak V_o and therefore to variations in grid bias.

Output Power, being proportional to the product of peak V_o and peak I_p, —each of which having been shown to be proportional to variations in grid bias— is proportional to the square of these variations, and thus the aerial current is directly proportional to these variations.

If the other variables are plotted against grid bias, one obtains a very clear picture of the process, Fig. 4. Pursuing our example, input power, efficiency, output power and aerial current will all be zero when the grid bias is adjusted to -750 volts and will reach their upper practical limit at -250 volts. Input power efficiency and aerial current will appear as straight lines, whilst output power will take a square law form. If now the bias were adjusted to -500 volts and an alternating modulating voltage of peak value 250 volts superimposed upon it, the aerial current corresponding with the -500 volts, or carrier, setting would be doubled at the positive and reduced to zero at the negative peaks of the alternating voltages. In other words, the carrier aerial current of amplitude I_c would be modulated 100 per cent. linearly.

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In this method of modulation the valve efficiency at maximum input, *i.e.*, at the positive peaks at full modulation of the modulating voltage, may be made equal to that for telegraphic working, by the choice of suitable values of driving voltage and grid bias. Thus it will be observed that, theoretically, for 100 per cent. modulation the aerial power in the quiescent, or carrier, condition may be one quarter of the maximum possible power of the transmitter for C.W. telegraphy, whilst the corresponding fraction for input and efficiency is one half.

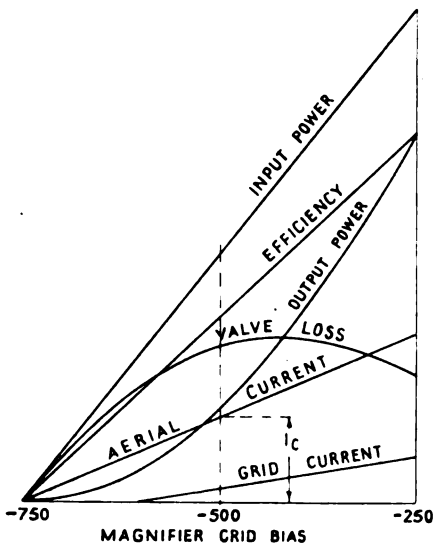

FIG. 4.

Actually, although the above statement holds in respect of the efficiency, the input and aerial power in the carrier condition must be rather less than one-half and one-quarter respectively of the C.W. telegraphy rating, if in the latter case the anode loss is the maximum that is permissible. This point is demonstrated by the curve of the Valve Loss in Fig. 4. For degrees of modulation less than 100 per cent., the carrier values of input and efficiency may be $\frac{1}{1 + M}$ of the respective C.W. ratings, and the carrier value of aerial power $\left(\frac{1}{1 + M}\right)^2$ of the C.W. rating, where M is the degree of modulation expressed as a fraction of one. Again, these fractions may be subject to slight modification on account of anode heating.

3. Distorting Effects Inherent to Magnifier Stage.

Having thus examined the basic principle of the method, the next step would be to consider the means, outlined in the introduction, which are employed in practice for varying the grid bias of a magnifier stage in sympathy with a microphone output ; but before doing so it would be as well to review the causes, inherent to the magnifier stage, which make the attainment of perfect linearity impossible. In this way we shall be able to judge the relative importance of the distorting effects arising in the magnifier stage and those introduced by the mechanism employed for varying the grid bias.

Of the former the first in order of magnitude is the curvature of the magnifier valve characteristics, the effect of which is to cause the straight load excursion,

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L_1 L_2 of Fig. 2, to become a curve, L_1 L_3 L_2, when transferred to the V_g I_p surface, Fig. 3. Over that portion where curvature exists peak I_p is obviously not proportional to variations in grid bias.

A second cause of distortion is that the ratios RMS/Peak and average/peak of I_p are not constant, as was assumed, over the full excursion of grid bias. The pulses of I_p are a reflection, apart from the effects of valve characteristic curvature, of that portion of the positive half cycle of the driving voltage in excess of the cut-off bias, —150 volts in our example Fig. 3. At one end of the grid bias excursion the pulse of I_p will be nearly a full half cycle of a sine-wave and at the other end will be the merest tip of a half cycle.

Both the ratios in question decrease as the grid bias is increased the result being to cause the load excursion of Fig. 2 to become curved as L_1 L_4 L_2. This, fortunately, opposes the effect of bottom curvature of the valve characteristics and tends to make it less than it otherwise would be.

A third cause of distortion is that due to the magnifier valve grid current, which constitutes a load on the source of driving voltage. When the grid bias is reduced, and the grid excursion consequently increased, this load increases and the amplitude of the driving voltage tends to fall. The result is a bending over at low values of grid bias of all the curves which are shown straight in Fig. 4. This cause of distortion can be largely overcome by providing an artificial load for the source of driving voltage sufficient to mask variations in the load due to the magnifier valve grid current.

These are the chief causes of non-linearity inherent to the magnifier stage and to illustrate their effects a set of curves plotted from actual measurements is shown in Fig. 5.

The circuits to which they apply are similar to those of Fig. 1. Two MT.12 valves in parallel working at an anode potential, V_B, of 2,500 volts were used for the magnifier stage. The driving voltage V_D, was 515 volts at zero input falling to 505 volts at maximum input due to magnifier grid current damping. Zero input occurred when the grid bias was adjusted to —705 volts, showing that the magnifier valve was "cutting-off" at $-705 + 515 = -190$ volts. Maximum input was reached with —250 volts grid bias, at which point the magnifier grid peak excursion was $-250 + 505 = +255$ volts. At —515 volts the grid bias was equal to the driving voltage and therefore the grid would just fail to go positive at the positive peaks of driving voltage.

The distorting effect of bottom curvature of the magnifier valve characteristics is shown clearly. The slight bending over at maximum input is due partly to top curvature of the characteristics, but more to the falling-off in driving voltage due to

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grid current damping. It will be observed that the curve of aerial current is practically straight down to one-tenth of its maximum amplitude and that it would be possible to obtain 85 per cent. sensibly linear modulation of the carrier aerial current which corresponds with a grid bias setting of −410 volts. The required swing of modulating voltage about this bias would be 160 volts. Note that on account of the falling-off in driving voltage the grid excursion would be only 150 volts for the positive half cycle of modulating voltage. The efficiency, anode output to anode input, at the setting for 85 per cent. modulation would be 42 per cent.

4. The Modulating Valve and Associated Circuits.

Having noted the causes of distortion inherent to the magnifier stage and the order of their magnitude, we can pass on now to a description of the means employed

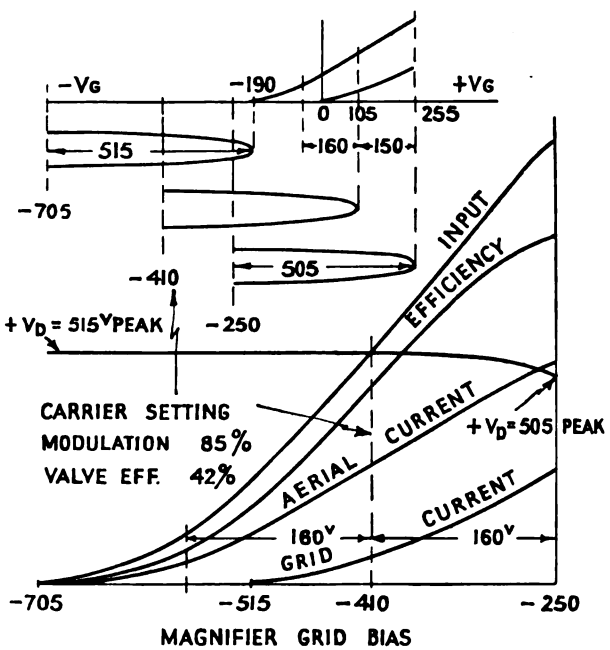

FIG. 5.

in practice for varying the grid bias of the magnifier stage in sympathy with a microphone output, and to an examination of the further causes of distortion introduced thereby.

As outlined in the introduction, the required variations in magnifier grid bias are obtained by using the anode-filament impedance of a triode to provide automatic grid bias and impressing on its grid the output from the microphone, suitably amplified.

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The circuit arrangements are shown in Fig. 6. It will be noticed that the filament of the modulating valve is connected to the magnifier grid and the anode to earth, for the reason that it has to pass the magnifier grid current. This fact necessitates heating the filament either with an insulated battery or with A.C. through a transformer. The latter method, which is the one shown in the diagram, is quite satisfactory and a perfect balance for hum can be obtained by adjustment of the potentiometer connected across the filament.

Similarly, the grid negative bias required for adjusting the impedance of the modulating valve tothe carrier setting must be provided by an insulated battery or by rectification from a source of supersonic frequency. The latter alternative is illustrated in the diagram, which indicates a way of obtaining the required negative

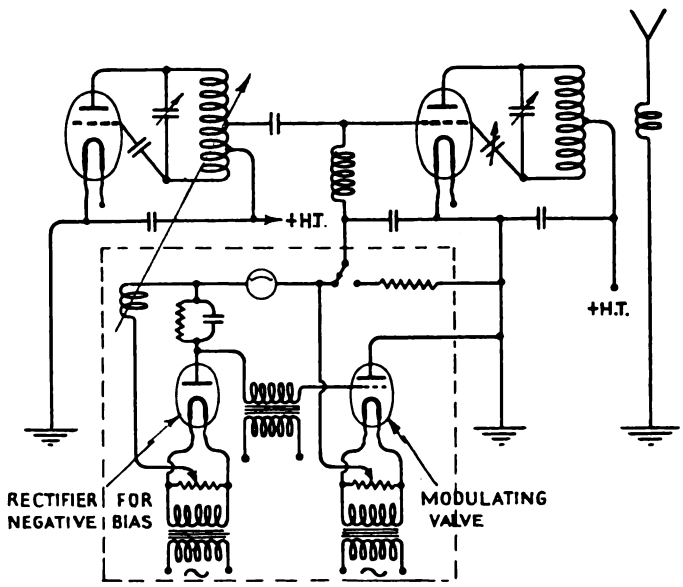

FIG. 6.

bias by rectification of H.F. voltage derived from the stage prior to the modulated magnifier. The rectifier for this purpose may be a small receiving valve, since the power taken is negligible, and no undesirable hum is introduced by heating its filament with A.C., as for the modulator valve.

The above way of obtaining negative bias for the modulating valve results in a reduction of the distortion due to bottom curvature, for the following reason. At low magnifier input values, where bottom curvature occurs, grid current is small or zero and the H.F. current in the prior stage rises, because it is relieved of the grid current damping. This in turn results in increased negative bias on the modulating valve grid, thus artificially increasing the amplitude of the negative swings of modulating voltage.

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An H.F. choke must be connected between the magnifier grid and the modulator filament, as otherwise the resistive high capacity paths to " earth " from batteries, transformers, etc., will give rise to a serious load on the source of driving voltage.

The only other apparatus required is a line to grid or microphone to grid transformer, as the case may be, and some means of checking the amplitude of the modulating voltage set-up across the transformer secondary.

A point which has to be considered in design is that all apparatus connected to the filament of the modulator valve is negative to earth by the amount of the magnifier valve grid bias. Insulation must be provided, therefore, to withstand the maximum value of this grid bias voltage, namely, that occurring at the negative peaks of the modulating voltage.

The modulating valve needs only to be very small compared with the magnifier valve, since it has to deal only with the watts represented by the power taken by the magnifier valve grid leak at the carrier setting. For instance, one L.S.5 valve is able, comfortably, to act as a modulating valve for a magnifier stage consisting of two M.T.12 valves in parallel working at a carrier input of 400 watts, anode potential 3,000 volts. It must have a total emission capable of handling the peak value of the magnifier grid current which flows at the positive peaks of modulating voltage at full modulation, and it must be equal to withstanding the value of magnifier grid bias voltage corresponding with the negative peaks of modulating voltage. It must have an impedance such that with a small negative bias, sufficient only to ensure the absence of grid current, the maximum rating of the magnifier stage may be obtained efficiently ; the small negative bias referred to being the difference between the positive peaks of modulating voltage set-up across the grid transformer secondary and the negative bias value for the carrier setting. Finally, its anode characteristics should be as linear as possible down to $I_p = 0$.

5. Limitation of Depth of Modulation and Distortion introduced by Modulating Valve.

The method just described for obtaining the required variations in the magnifier stage grid bias lends itself readily to static measurements of the depth and linearity of modulation, since the alternating modulating voltage may be simulated statically by varying the modulating valve negative bias. The simplicity of the method is self-evident, but unfortunately, for two reasons, it reduces considerably the percentage of linear modulaton we have seen to be attainable even when the variations in magnifier grid bias are proportional to the modulating voltage.

(A) It imposes a limit to the excursion of magnifier grid bias.

(B) The relationship between variations in modulating valve negative bias and the magnifier stage grid bias is far from linear.

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Taking these two effects in the order given, it is obvious that the greatest possible value of magnifier grid bias obtainable is that corresponding to the value of negative bias sufficient to "cut-off" the modulating valve. Under that condition the magnifier valve will, in effect, be working with an open grid, and the grid leak condenser will charge up and bias back the magnifier grid to the point where the positive peaks of driving voltage just fail to produce grid current, at which point the charging up process will, of course, cease. Increasing the modulating valve negative bias beyond the cut-off value will not effect any further decrease in input, efficiency or aerial current.

Fig. 7 illustrates the effect on the possible depth of modulation of this limitation. X and Y represent the load excursions on the V_g I_p surface for two magnifier valves of different characteristics. The maximum magnifier grid bias obtainable from the modulating valve will be M volts, such that the positive peaks of the driving voltage V_D just fail to produce grid current.

The greatest possible depth of modulation for X would be A/B of a carrier of amplitude B, *i.e.*, about 50 per cent. as drawn.

On the other hand, in the case of Y, zero input and zero grid current coincide and therefore, disregarding non-linearity, it would be possible to obtain 100 per cent. modulation of a carrier of amplitude C.

TABLE 1.

Magnifier Valve	m.	V_B.	% Modulation
MT. 9	90	4,000	90
MT. 7a	80	3,000	90
MT. 5	40	1,500	90
MT. 9	90	6,000	85
MT. 7a	80	10,000	75
MT. 12	20	2,500	75
DET. 1	11	1,000	35
MT. 12	20	8,500	28

The extent of this limitation in any particular case is clearly a function of the magnification factor of the magnifier valve and the anode potential, V_B. Some representative examples are given in Table 1. The percentage modulation shown is the maximum obtainable disregarding non-linearity.

This limitation is a very definite disadvantage of Direct Current Grid Modulation, since it restricts the designer in his choice of magnifier valves and anode potential.

Coming now to the distortion introduced by the modulating valve, the two

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chief causes of such distortion are bottom curvature of the magnifier valve grid characteristics and bottom curvature of the modulating valve anode characteristics.

These effects are best understood by examination of the V_g I_p characteristics of the modulating valve. Fig. 8 gives these characteristics for an L.S.5 valve, and the curve marked Mag I_G — Mod. I_p drawn thereon is the grid current of a magnifier stage consisting of two M.T.12 valves with an L.S.5 as the modulating valve. The circuits used were as shown in Fig. 6, and the curve was obtained statically by varying in steps the negative bias of the modulating valve.

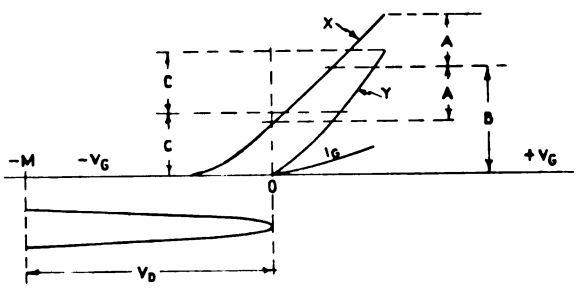

FIG. 7.

The grid current of the magnifier stage, since it flows through the modulating valve, is naturally the anode current of the latter. Therefore, the potential which existed between its filament and anode for any particular setting of the negative bias may be read-off from the intersection of the grid current curve and the modulating valve anode characteristics.

The result is the curve marked Mag G.B. — Mod. V_p, the potential between filament and anode of the modulating valve being obviously identical with the grid bias of the magnifier valves.

It will be observed that the result of bottom curvature of the magnifier grid current and of the modulating valve characteristics is a considerable departure from linearity in the relationship between modulating valve negative bias and magnifier valve grid bias variations.

Thus, the departure from true linearity inherent to the magnifier stage, as illustrated in Fig. 5, is increased to the extent indicated in Fig. 8.

Since, input, efficiency and aerial current all increase as magnifier grid bias is decreased, one would expect to find the curves of these variables, when plotted against modulating valve negative bias, to be an inverted reflection of the curve of magnifier grid bias in Fig. 8, plus an additional curvature due to the inherent non-linearity of the magnifier stage.

Fig. 9 shows a set of curves taken from actual measurements. The magnifier stage was again two M.T.12 valves in parallel, working at an anode potential of 2,500 volts. The modulating valve was one L.S.5. The amplitude of the positive peaks of the driving voltage, V_D, was 525 volts falling to 515 volts at maximum input

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due to magnifier grid current damping of the source of driving voltage. Note that the curves of input, efficiency and aerial current become parallel to the base line just beyond the point where grid current starts, for the reason given in the first

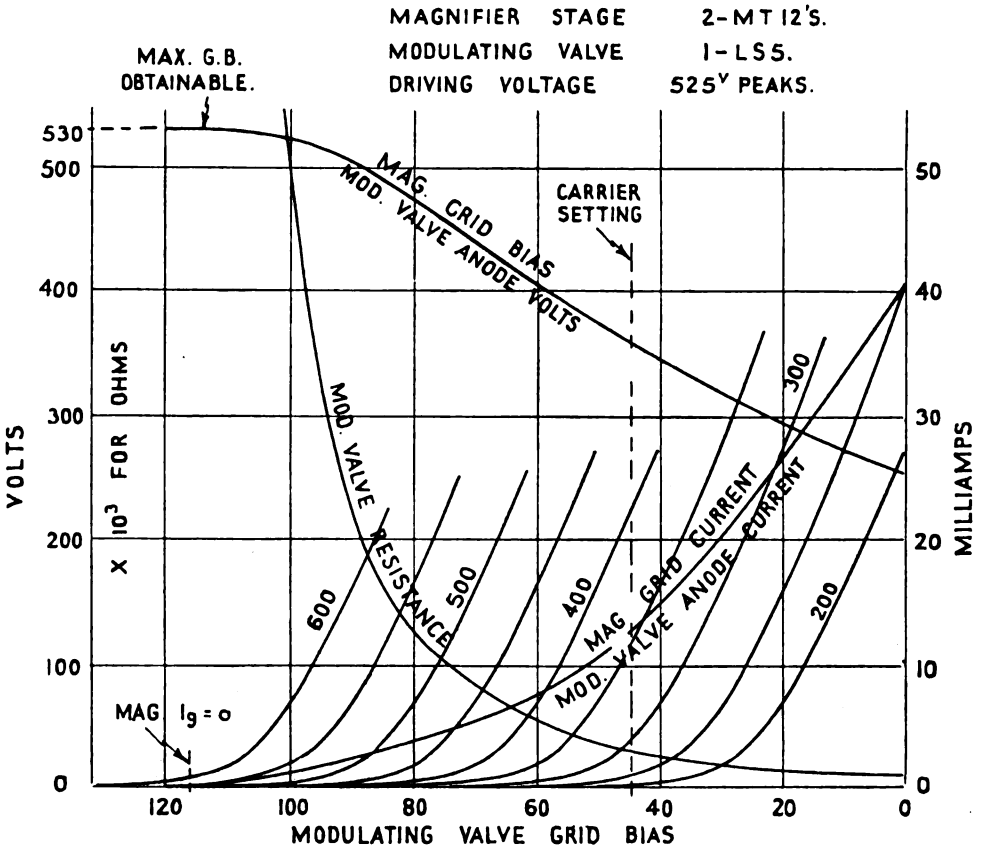

FIG 8.

half of this section. It will be seen that the greatest depth of sensibly linear modulation obtainable would be 63 per cent. of the carrier aerial current which corresponds with a setting of −45 volts bias on the modulating valve. The peak amplitude of the modulating voltage required to give full modulation would be 45 volts, measured across the secondary of the grid transformer. The efficiency at this carrier setting would be 49 per cent. anode output to anode input.

The above may be taken as an average example of the depth of modulation and degree of linearity attainable by this method of modulation with the transmitting valves in general use in the Marconi Company, when working at their normal rated anode potential.

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The depth of modulation could be increased to a little over 70 per cent. for the example in question, with a consequently somewhat reduced carrier power if no more than good commercial quality speech were required.

6. Comparison with other Methods of Modulation.

On the score of the depth and linearity of modulation attainable, both the choke Control and Power Amplifier methods are superior to the Direct Current Grid Method.

With Choke Control it is possible, by using a higher voltage for the modulator than for the oscillator valve, to obtain 100 per cent. modulation with almost perfect linearity.

The Power Amplifier method originates its modulation in a Choke Controlled stage, the modulated output of which is impressed on the grid of a magnifier stage having a fixed bias, this constituting the difference between it and the Direct Current Grid Method, in which the driving voltage is fixed and the bias modulated.

In the Power Amplifier Method the percentage modulation attainable obviously depends only on the percentage modulation of the choke controlled stage ; whilst the degree of linearity depends on the linearity of the choke controlled stage, on the straightness of the magnifier valve anode characteristics and on the value of magnifier valve efficiency demanded. Power Amplifiers are in operation, adjusted for 100 per cent. modulation, linear within the definition of linearity agreed upon internationally, and having a magnifier valve efficiency of 32 per cent.

In the Direct Current Grid Method, as has been shown, 100 per cent. modulation would be only attainable if the characteristics of the magnifier valve were such that anode and grid current cut-off simultaneously at the anode voltage employed. One hundred per cent. modulation with this method must of necessity imply grave non-linearity, since as shown on page 14, in order that the aerial current may be reduced to zero at the negative peaks of modulating voltage the positive peaks of driving voltage must withdraw beyond the cut-off point of the magnifier anode feed, with consequent serious effects due to bottom curvature of the magnifier anode characteristics. In addition, there is the distortion introduced by the modulating valve.

It would appear, therefore, that the Direct Current Grid Method of modulation cannot provide the depth of linear modulation demanded by present day broadcasting standards, as can both the Choke Control and Power Amplifier Methods.

Coming now to the question of total anode power required for equal modulated power in the aerial, there is no great difference between one method and another ; whether the magnifier valves are worked at C.W. telegraphy efficiency and anode modulation provided by valves taking power comparable with that taken by the magnifiers, or whether they are worked at the low efficiency involved by an adjust-

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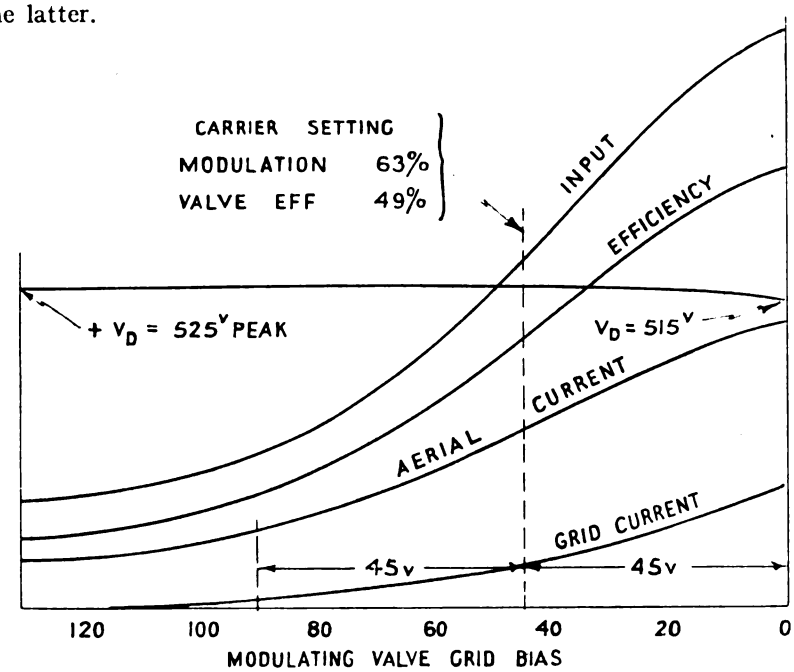
ment which renders them capable of magnifying linearly a modulated grid input. What difference exists favours the Direct Current Grid Method, since in that method no power is required for modulating the magnifier grid input.

In matters of filament power, and bulk and cost of apparatus required, there are, however, greater differences, the greatest discrepancy in these respects lying between the Choke Control and Direct Current Grid Methods, the advantage being with the latter.



Magnifier Stage 2-*MT*12's *Aerial Carrier Power* 175 *Watts.*
Modulating Valve 1-*LS*5 *Anode Volts* 2500

FIG. 9.

To illustrate the extent of the advantage Table 2 gives the principle data for a Choke and Grid controlled transmitter.

The example is of a transmitter having one M.T.7A as the final magnifier. The C.W. input rating is taken as being V_p = 8,000 volts, I_p = 325 m/a, 2,600 watts. It has been assumed that at the C.W. rating the H.F. circuits have no more than the proper factor of safety and that for Choke Control the anode volts must be lowered to the point at which under full modulation they will not exceed 8,000 volts. Similarly, the feed must be lowered in the same proportion as otherwise the filament will limit unless overheated.

The driving stages are omitted from the table since they are unaffected by the

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choice of modulation method. It should be noted, however, in this connection, that Grid Control could not be employed if the transmitter were a Self-Oscillator.

TABLE 2.

	Grid Control.	Choke Control.
Magnifier Valve	1-MT. 7a	1-MT. 7a
,, ,, Filament Watts	300	300
Modulator Valve	1-DET. 1	1-MT. 9a
,, ,, Filament Watts	12	145
Sub-Modulator Valve	—	1-MT. 4L
,, ,, Filament Watts ...	—	80
Total Filament Watts	312	525
Anode Volts	8,000	5,000
,, ,, Full Modulation Peak	8,000	7,850
Anode Feed —Magnifier m.a	185	200
,, ,, Modulator m.a	—	200
Speech Choke	—	To carry 400 m/a
Magnifier Anode Input—Watts	1,500	1,000
Total ,, ,, — ,, ...	1,500	2,000
Aerial Carrier Power—Watts	560	650
Mag. Anode Input Aerial Carrier Power ...	37%	65%
Percentage Modulation...	75%	57%

For general purpose transmitters, Naval, Military, etc., in which space and ease of changing from C.W. to telephony or I.C.W. are more important than the attainment of perfect reproduction, the Direct Current Grid Method has great advantages over any other, since not only is the additional apparatus required for modulation purposes far less for Grid than for Choke Control, as can be seen from Table 2, but, in addition, Grid Control makes possible an extremely simple change-over from C.W. to Telephony.

Referring to Fig. 6, it will be seen that the low potential end of the grid choke is taken to the common point of a two-way switch. One side of the switch is connected to the filament of the modulating valve, and the other to a grid leak resistance of suitable value for the C.W. adjustment of the magnifier. The switch can be provided with additional contacts to switch-on the heating for the modulating and grid negative rectifier valves, and to close the microphone circuit. A third position can be provided for starting-up a buzzer, or audio-frequency oscillator, and connecting it to the primary of the grid transformer for I.C.W. transmission. The whole of this apparatus is at low potential and may be mounted as a separate unit in any convenient part of a ship's cabin or army lorry.

For installations of this nature a sensitive galvanometer in the grid circuit of the modulating valve serves as a satisfactory level indicator of the modulating voltage, since the presence of grid current indicates that the peak amplitude of the modulating voltage is equal to the negative bias and that, therefore, the transmitter is fully modulated.

F. C. LUNNON.

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MARCONI NEWS AND NOTES

MARINE WIRELESS TELEPHONY.

WHITE STAR LINER "HOMERIC" EQUIPPED WITH MARCHESE MARCONI'S NEW APPARATUS.

"Homeric" Telephone Receiver.

THE first ship fitted for commercial operation with the new short-wave marine telephone apparatus developed by Marchese Marconi is the White Star Liner "Homeric." Marchese Marconi's successful experiments with this type of equipment on his yacht "Elettra," were described in THE MARCONI REVIEW, Nos. 19 and 20.

The British Post Office announced on May 29th the opening of a regular telephone service from the "Homeric" to Great Britain and the United States of America, following a series of tests between the ship in Mid-Atlantic and the authorities on each side. The service has now been extended to include France, Switzerland, and other countries.

During the tests conversations which took place between England and the "Homeric" over distances of more than 2,000 miles and also between the liner and New York were reported by officials to be **the best in clearness and quality ever heard from a ship on the Atlantic.** These experts, in fact, expressed themselves as amazed at the results achieved.

On May 28th officers on board the "Homeric" rang up the White Star Line offices in London and were able to discuss easily the progress of the voyage and to compare the state of the weather 1,200 miles out in the Atlantic with that in London.

Telephone conversations also took place between representatives of the Marconi Company at Marconi House, London, and officers on the "Homeric," congratulations being sent to the wireless engineers and operators on board upon their success with the new Marconi apparatus fitted for the first time for commercial operation.

Demonstration of Remarkable Quality.

The remarkable quality of the telephone service available through this installation was demonstrated to thousands of wireless listeners in the British Isles on Friday evening, June 6th, when a conversation between a passenger on the "Homeric," 1,000 miles out from Southampton and Mr. Harold Nicolson, in the B.B.C. studios

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at Savoy Hill, London, was broadcast by the British Broadcasting Corporation. Every word of the passenger's description of the sea scene before him and of the day's happenings on board was as clearly heard as the questions and comments of Mr. Nicolson speaking into the microphone in London. Particularly noticeable was the clarity of the speech from mid-Atlantic and the absence of " background," that annoying hum or crackling which sometimes ruins long-distance telephony even by land-line.

Organisation of the Service.

The shore end of the service in Great Britian is carried out by the Post Office, the Rugby wireless station being used for transmission to the " Homeric," and the Baldock station in Hertfordshire for reception from the ship. These stations are connected by landlines with the London Trunk Exchange where the service is controlled.

On board the " Homeric," a special extension of the Marconi cabin has been erected to house the telephone equipment, close to the telephone room from which passengers speak to their friends ashore. The telephone installation operates on wavelengths of about 24 and 70 metres, with a power of 2 kilowatts in the aerial.

With a telephone transmitter of this type Marchese Marconi has carried on wireless telephone conversations from the S.Y. " Elettra " in the Mediterranean, with Sydney, London, Montreal, Bombay, Cape Town, New York, Buenos Aires, and Rio de Janeiro. On April 30th he was " interviewed " on board the " Elettra " by a journalist who was in New York, 4,400 miles away, and the interview was re-broadcast throughout the United States.

With this apparatus therefore the telephone service from the " Homeric " and any other ships similarly equipped will be capable of a very wide range, making it possible, if required in the future, to link up with the shore telephone circuits in many countries and at almost any distance.

The charge for the ship-to-shore telephone service is £4 10s. 0d. for the first three minutes and £1 10s. 0d. for each additional minute to Great Britain and the United States.

Tenth Anniversary of Dame Melba's First Broadcast.

June 15th was an historic date in the development of broadcasting. It was on this date ten years ago that Dame Melba broadcast her memorable concert from the Marconi Company's experimental station at Chelmsford. The occasion was the first on which an artist of international reputation had sung before the microphone, and was virtually the birth of entertainment broadcasting in Great Britain.

Next day there arrived from most European countries telegrams containing expressions of wonder and appreciation. At Oslo the signals were so strong that the operator at the wireless station, some distance from the town, relayed the music by telephone to the principal newspaper offices.

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Following the great public interest aroused by Dame Melba's concert, the famous Marconi experimental station at Writtle was established in 1921 to give occasional broadcasts for an ever-increasing number of listeners. The first 2LO, installed at Marconi House, London, made its appearance on the ether early in 1922 as a supplementary experimental station to Writtle.

With the evolution of broadcasting from the experimental stage of ten years ago to the great public service it is to-day, the Marconi Works at Chelmsford has maintained its importance as a centre of pioneer work. It is the site to-day of G5SW, the world-wide short-wave broadcasting station, and was the first home of 5XX before its removal to Daventry.

Death of Mr. Jack Cave.

It was with much regret that the Marconi Company received the news of the death on the 14th inst., of Mr. Jack Cave, one of their earliest pioneers.

Mr. Cave was in his 58th year and had been ill for several weeks.

His special knowledge of the technique of glass blowing and his skill as a master instrument maker led to his appointment in 1897 to the personal research staff of Mr. Marconi, whom he assisted in the construction of much of the early apparatus.

He was thus the first mechanic to be associated with the commercial development of wireless telegraphy, and under him the art of coherer manufacture and testing reached a high degree of precision and performance.

He began his work at Bournemouth, it was continued at Poole, and in 1899 commercial manufacture was begun at Chelmsford. With the advent of the magnetic detector superseding the coherer, Mr. Cave's wide practical knowledge led to his appointment in 1907 as Foreman of the Machine Shop and he retained this position in the new Works which were opened in 1912. In 1922 he was appointed Chief Rate Fixer which position he held at the time of his death.

He was highly esteemed by all who knew him. He was greatly interested in sport especially running and boxing and was one of the Founders, and a Vice-President, of the Marconi Athletic and Social Club.

Mr. Cave leaves a widow and two sons.

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THE MARCONI REVIEW

July, 1930

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TONE MODULATION OF TELEGRAPHIC TRANSMITTERS.

The speed at which telegraphic traffic on short waves can be handled is almost entirely limited by the effects of fading, therefore any method by which fading may be reduced merits considerable attention.

One such method is to modulate the carrier wave of the telegraphic transmitter by a tone frequency, and it is pointed out in the following article that this represents the best means at our disposal at the present time for increasing the speed of telegraphic traffic, as distinct from speech and picture transmissions.

The effects of tone modulation on both the transmitter and receiver are given, and the article concludes with a summary of the advantages, conditions and limitations of the method.

Effect of Modulation.

WHILE fading may be pronounced at any instant of time between two stations communicating, say, on a 20,000 kilocycle frequency (15 metres), it is an established fact that on a second frequency only differing by a few hundred cycles from the first, fading may be appreciably less or even non-existant ; again, at another instant of time the effect may be such that there is no appreciable fading on the former but bad fading on the latter frequency. It follows that if two frequencies can be transmitted simultaneously and received simultaneously, the evils of fading are reduced, while if we take some particular frequency and transmit on several frequencies above and below this datum, then, provided our receiver is sensitive over the full wave band, the improvement becomes more marked ; but this group of frequencies is precisely such as is created when a C.W. Transmitter is tone modulated, and the resultant improvement in reception of morse signals in actual practice affords a striking proof of the validity of the foregoing statements. At some stations the speed has increased, in other cases, where high speeds were already attained over certain periods, the amount of " words once " traffic has gone up to five times the original average. If, however, such results are to follow it is important to appreciate the limitations outlined in the following brief notes.

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Side Bands.

Were it possible to produce a pure sine form continuous wave and modulate it to some pure sine variation in amplitude, Fig. 1, the result would be only three waves, that is, the original wave and an upper and lower side wave whose frequencies are respectively original frequency plus modulation frequency and original minus modulation frequency ; tabulating these we have :

Carrier wave of original frequency.
Upper Side Wave, of Carrier + Fundamental Modulation Frequency.
Lower Side Wave, of Carrier — Fundamental Modulation Frequency.

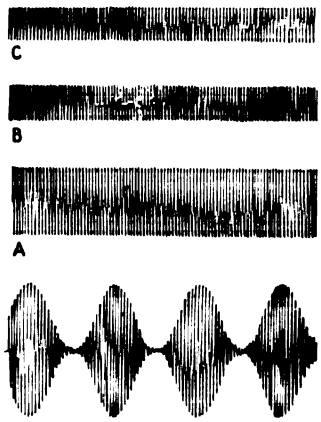

FIG. 1.

On the other hand if modulation gives a square form of variation in amplitude, Figs. 2 and 3, there will be a series of waves as follows :

Carrier Wave.	
Upper Side Band.	Carrier + Fundamental.
	Carrier + 3rd Harmonic (i.e. plus three times fundamental frequency).
	Carrier + 5th Harmonic.
Lower Side Band.	Carrier — Fundamental.
	Carrier — 3rd Harmonic (i.e. minus three times fundamental frequency).
	Carrier — 5th Harmonic.

and so on, indefinitely. The higher and lower frequencies on either side of the carrier frequency constitute the upper and lower side band waves.

Power Distribution.

Complete, or 100 per cent. modulation is indicated in Figs. 1 and 3 and partial, say 50 per cent. modulation, in Fig. 4. It is fairly obvious that the amplitude of the

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side waves, and hence the power conveyed by them, increases with the percentage of modulation, and it may be shown that for complete sinusoidal modulation one third of the total power radiated resides in the side bands, while for complete square form modulation one half of the power resides in the side bands : thus in the case of pure sine modulation one third of the total output is carried by two side waves, while in the case of square form modulation one half is spread over a wide series of upper and lower frequencies, residing mainly in the earlier components.

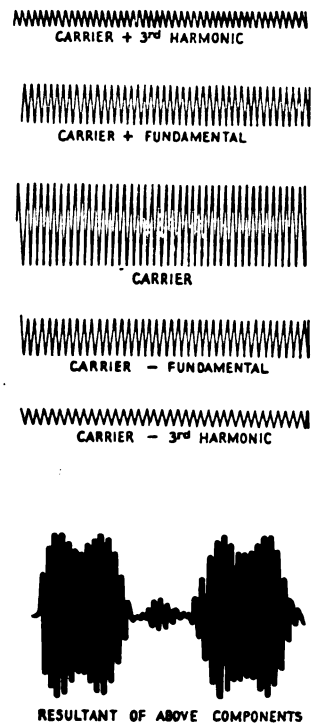

FIG. 2. *The first five radio components of square wave formation.*

Width of Band.

An impression will probably be given that the wider the band and the greater the number of side frequencies, the better the results, but this is emphatically not so because, in the first place, it has become apparent that a diverse fading effect exists between two frequencies removed from each other by a very slight amount, such as a separation of 250 cycles between 20,000,000 and 20,000,250 cycles, which implies that a narrow band of a few frequencies differing from each other by only a slight amount, tends to maintain uniform reception. In the second place when reception is highly selective and receivers are equipped with filter circuits (limiting the width of band it is possible to receive for one channel) the narrow wave band will convey more effective energy and yield greater effective signal strength than a wide band, where a large percentage of the side frequencies is attenuated in the receiver filters : this point has been proved at many receiving stations.

Finally the most important consideration of all is that the narrow band occupies less space in the Ether.

Receiver Band.

Since the transmitted power is now spread over several frequencies it is clear that the receiver should be capable of receiving simultaneously all these frequencies ; in the case of the Marconi Beam Receiver the first filter circuit is adjusted to a band 5,000 cycles wide (157,500 cycles to 152,500 etc.) the original idea being to allow a variation of 2,500 cycles on either side of the first heterodyne beat frequency and

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thus allow for a drift of that amount up or down in either transmitter or receiver. We may adopt 5,000 cycles as typical of a modern type receiver filter band, bearing in mind the probability of narrower widths in the near future.

Now in practice, probably because either the modulating or the fundamental wave is symmetrically distorted, the odd harmonics appear to be always present

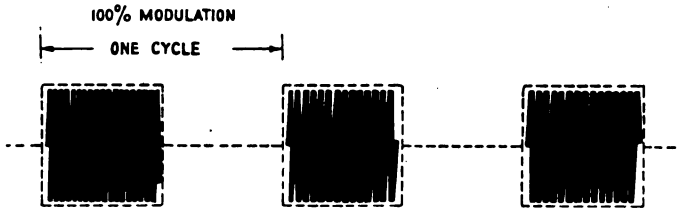

FIG. 3.
A series of dots is equivalent to 100% *square wave modulation at the dot frequency.*

and sometimes pronounced ; therefore in considering the effect of, say, a 1000 cycle modulation, the more important side frequencies will be :—

Carrier Frequency ± 1,000 cycles (1st Harmonic)
,, ,, ± 3,000 ,, (3rd ,,)
,, ,, ± 5,000 ,, (5th ,,)

and from these figures it will be seen that the 2nd and 3rd terms lie outside the receiver filter band and are lost. On the other hand, taking a 250 cycle modulation we get :—

Carrier Frequency ± 250 cycles 1st Harmonic)
,, ,, ± 750 ,, (3rd ,,)
,, ,, ± 1,250 ,, (5th ,,)

in which case both 3rd and 5th terms lie within the receiver filter band.

In a few cases of non-symmetrical distortion the even harmonics may be prominent but whether the harmonics are odd or even in no way alters the argument.

Considerations of the conditions at the Receiver thus point to the desirability of a narrow band.

Lower Limit of Modulation Frequency.

Apart altogether from the main issue of overcoming fading, the frequency of modulation has an obvious lower limit, for it should be above the speed of morse keying. A speed of 150 words per minute is equivalent to 60 dots per second, in other words the time period for a dot mark is 120th of a second ; at such a speed and taking the frequency of modulation to be 250 cycles, there will be slightly more than two impulses to form or sustain one dot mark, and for a modern receiver, equipped with a limiting device this is sufficient for good tape formation.

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Actually, with a modern receiver, the question of *note frequency* has little to do with signal formation, for whether there be two impulses per dot, as with a 250 cycle note, or twelve impulses, as with a 1,500 cycle note, the energy passed through the rectifier, that is, the energy effective for marking, remains virtually constant.

Power Radiated.

The effect of modulation is to modify the even radiation of pure C.W. either into periods of radiation and periods of non-radiation, or into periods of rising and diminishing radiation ; obviously from the point of view of effective power radiated it is preferable that the periods be balanced. For ordinary telegraphic transmission, however, a compromise is necessary in order to obtain reasonable power radiation ; this calls for a somewhat unbalanced modulating wave form, but when modulation is effected by means of a tone oscillator it is quite possible, indeed practical, to mould the modulation envelope either by suitable adjustments in the circuit constants, or by double rectification of the oscillator output.

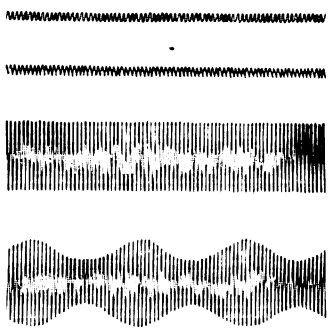

FIG. 4.

When modulation is effected by full wave rectified (unsmoothed) single phase A.C. supply little can be done to mould the wave form, though with a good machine the resulting wave form is generally quite satisfactory.

When modulating by means of an unsmoothed rectified A.C. supply it is advisable to include a certain amount of capacity between the H.T. lead and earth as this rounds off the wave " corners " and reduces harmonics ; also it causes a certain percentage of pure C.W. (residual C.W.) which, as will be shown in the next paragraph, is an advantage.

Before leaving the subject of power radiated it is well to point out that by careful design all harmonics after the first can be practically suppressed.

Conditions and Speed.

It seems to the writer that the only factor for good tape formation at very high speeds is the condition of the space intervening between transmitter and receiver. When conditions are good and stable, in other words favourable to very high speeds, we approach the stage during which pure C.W., with its energy concentrated into a single unfading frequency will give stronger signals and higher speeds than modulated C.W. But conditions can seldom be trusted, and modulated C.W. gives an unquestioned improvement in traffic at most times, so that some compromise seems indicated ;

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thus in many instances and in general practice, it will be an advantage to run with a certain amount of residual C.W., provided that the system of keying is such that the whole of the received energy is available to form signals.

As a side light on the value of modulation the writer has observed while receiving signals for which the modulation has been only 30 per cent, and even less, that when conditions were in any way poor the large C.W. component has almost entirely disappeared, whereas the sidebands were still coming through to give commercially strong signals.

Diversity Reception and Tone Modulated Signals.

It has been stated that frequencies differing from each other have diverse rates of fading : it is equally true, in fact it follows from what is known of wave propagation in our variable medium, that the fading of waves of the same frequency at points removed from one another by an appreciable amount, say twenty or more wavelengths, is diverse ; thus a similar effect to modulating the transmitted wave is attained by receiving the signals at several places separated from each other by some little distance. In practice three points of reception is found to be a satisfactory arrangement.

In cases where " Diversity " reception is in operation the logical procedure would be to employ pure C.W. transmission, but here again in practice some compromise is more effective.

Choice of Modulation Frequency.

We might summarise the last few paragraphs somewhat arbitrarily as follows :

(A) For a wide aperture Beam Reception aerial system, or for combined " Beam " and " Diversity " Reception, *i.e.*, three small " Beam " aerial systems separated for Diversity fading, a modulation frequency of 250 cycles is suitable.

(B) For small " Beam " aerial systems, or for Diversity Reception employing three simple aerials, a modulation frequency of 500 cycles is suitable.

(C) For Broadcast Reception a modulation frequency of 1,000 cycles is suitable.

Conclusion.

Modulation, by creating side bands of different frequencies is a means of neutralising the effect of fading.

There are two methods of controlling the width of band, first by the purity of wave formation and secondly by the frequency of the modulating note.

With respect to the circumstances surrounding modulation, two facts emerge, first the necessity of keeping the transmitted wave band within such limits as will avoid interfering with other services, and secondly the necessity of keeping the frequencies within the reasonable limits of selective reception, *i.e.*, within the band to

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which the corresponding receiver is designed—otherwise an appreciable amount of the received energy will be cut off in the filter unit and lost to the subsequent circuits.

It must not be over looked that under very stable conditions pure C.W. will give higher speeds than tone modulated C.W. because the energy is concentrated into a single frequency in the former, and distributed over several frequencies in the latter ; nevertheless the average results over any considerable period are strongly in favour of modulation. Generally speaking a modulated wave does not rise to the same high peak values of signal strength as a pure C.W. wave, because some of the energy is in the side bands, yet for this very reason the energy arriving at the receiving station has a much more even flow, with the resultant improvement in traffic.

The writer is indebted to Mr. A. W. Ladner for figures 1, 2, and 4.

N. WELLS.

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MARCONI SHORT WAVE TELEGRAPH TRANSMITTER

TYPE S100

The Transmitter described below has been designed for permanent installation in a vehicle or at a fixed point, and is so arranged that either telegraphic or telephonic communication can be maintained over comparatively large distances on short wave lengths.

Simplicity of control and complete accessibility are the outstanding features of the S100 Transmitter and these facts together with the easily erected aerial system and high overall efficiency of the set have proved to be of considerable use in maintaining reliable short wave communication under severe conditions of service.

THE S100 Transmitter, a photograph of which is shown in Fig 1, is arranged to cover a wave range of from 30 to 60 meters by means of two interchangeable inductance coils.

It will be evident from the photograph that the component parts are so arranged as to form a compact and accessible unit. This accessibility enables the operator to have complete control of the apparatus.

Modifications of the S100 Transmitter have been designed in order to enable (*a*) a drive to be used as the fundamental source of oscillations in place of the self oscillator, and (*b*) telephony modulation to be applied either to the driven or undriven telegraph set.

The various combinations that can be obtained are given below :—

S100 Undriven telegraph transmitter.

S100*a* Complete driven transmitter arranged either for telegraphy or telephony.

S100*b* Driven telegraph transmitter.

S100*c* Complete undriven transmitter arranged either for telegraphy or telephony.

Range.

As is well known the range obtainable by short wave transmitters depends to a large extent on conditions determined by the time of day or night at which transmission is carried out and also on the period of the year and on the wavelength used.

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Considerable information on these points will be found in the article on " World Wide Communications with short Wireless Waves " published in No. 17 of THE MARCONI REVIEW for February, 1930.

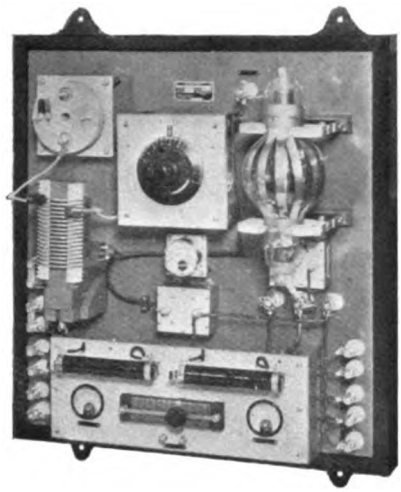

FIG. 1.

It is therefore impossible to define the range which will be obtainable from a transmitter of this nature unless the exact conditions under which the transmitter is working are known.

A short table is, however, appended indicating roughly the distances at which transmission is effective during periods of daylight and darkness. These figures are based on the supposition that reasonably open country and favourable atmospheric conditions prevail.

DAYLIGHT.	
50 — 60 metres	0 — 400 miles.
40 — 50 ,,	200 — 300 miles and upwards.
30 — 40 ,,	From 250 miles upwards.

NIGHT.	
50 — 60 metres.	0 — 300 miles.
30 — 50 metres.	From 300 miles upwards.

Equipment.

The normal equipment provided with the S100 series of Telegraph Transmitters includes the following :—

Transmitter Panel.
Manipulating Key.
Motor Generator Set providing both high and low tension.
Accumulator Battery for low tension supply.
Switchboard.
Wavemeter.
Aerial System.

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Additional items for combined C.W. Telegraphy and Telephony include :—

Telephone Modulator Panel.
Microphone.

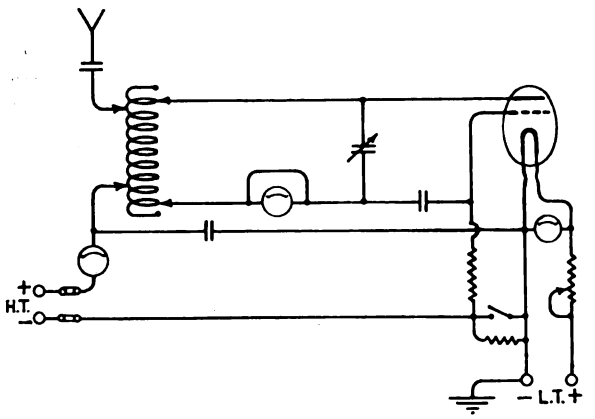

FIG. 2.

Power Supply.

The power supply to the anode of the transmitter valve and the filament supply to this valve, are obtained from separate generators which are coupled to a motor wound to suit the available electric supply.

The H.T. generator in the case of the S100 transmitter delivers 2,500 volts, and the L.T. generator delivers up to 16 volts. The accumulator battery of 14 volts is normally floated across the L.T. generator.

The Transmitter.

The components of the transmitter are fixed to a panel which is arranged for wall mounting in a vertical position. A simplified diagram of the transmitting circuit is shown in Fig. 2. It will be seen that a fundamental oscillatory circuit is employed with an auto coupling to the aerial. The aerial tuning inductance is tapped for grid, anode, aerial and earth connections and the required wavelength is finally obtained by means of the variable condenser which is connected across the grid and anode tappings of the aerial tuning inductance. The closed H.F. circuit of the valve includes an inductance and a tuning condenser, and is completed to earth through a resistance which is inserted between the grid and filament. The anode of the valve receives H.T. through the tuning inductance, and the negative of the H.T. supply is connected to earth, keying being accomplished by means of a key inserted in the return part of the grid circuit, and arranged so that when it is open the grid circuit is broken and also the negative of the high tension supply is isolated from earth.

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A feed milliammeter is inserted in the high tension supply circuit to the valve and an indicator in the form of a hot wire ammeter is provided in the oscillatory circuit as an indication that the transmitter is working.

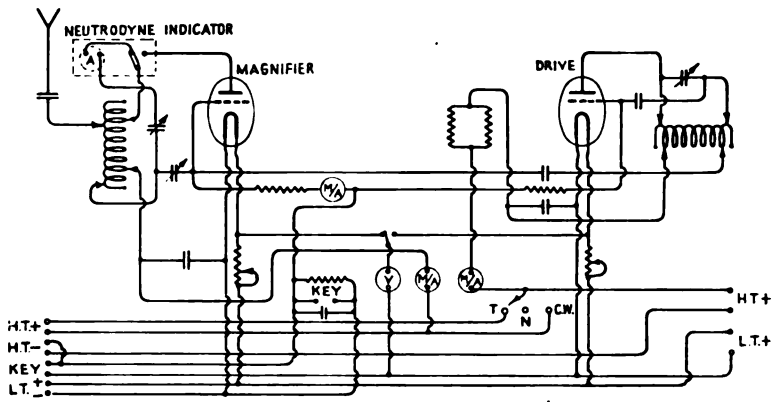

FIG. 3.

Aerial System.

A single wire aerial 30 metres in length is provided. Any length of aerial however may be used as long as its length exceeds 12 metres approximately.

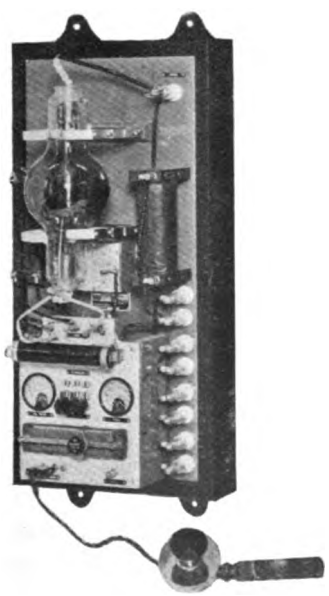

FIG. 4.

Driven Telegraph Transmitter Type S100B.

In place of the undriven self oscillator employed in the S100 transmitter a power magnifier and drive are included in the S100*b* telegraph Transmitter.

A diagram of connections of the set is given in Fig. 3. The drive circuit employs a MT12A valve and a similar oscillatory circuit to that employed on type S100 set.

The power magnifier valve is neutrodyned by means of a .000055 mfd. variable condenser. An indicator is fitted in this circuit to enable the valve to be properly neutrodyned. The method of neutrodyning is as follows. The proper coils are inserted in their correct positions and all connections to these coils made with the exception

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of the aerial tap which should be left disconnected. The link on the neutrodyne ammeter should be placed in the " neutrodyne " position and the plug should be inserted in the " neutrodyne " socket. H.T. should then be applied and

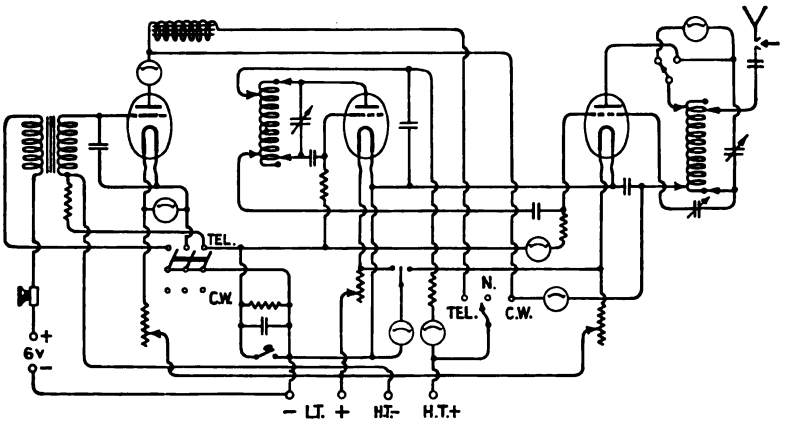

FIG. 5.

on pressing the key the drive valve should oscillate. The wavelength should be checked on a wavemeter and the magnifier should be tuned to the drive by means of its condenser. The neutrodyne condenser should then be adjusted until the reading of the meter is reduced to zero.

The set is now balanced for the particular wavelength and the connections should be made for normal working.

Variable tuning condensers are provided for tuning (*a*) the drive closed circuit and (*b*) the magnifier closed circuit, each of these condensers being provided with removable extension handles which eliminate hand capacity effects during tuning.

In other ways the driven telegraph transmitter resembles the undriven telegraph transmitter, the method of keying being similar and interrupting simultaneously the grid filament circuit of both the power magnifier and drive valves and also the negative high tension connection to earth.

Telephone Modulator Panel.

The telephone modulator panel which can be used in conjunction with either the driven or the undriven transmitter comprises a MT12A valve on the grid of which the speech variations are impressed through a microphone. The anode of this valve is connected through a speech choke to the anode of the oscillating valve on the telegraph panel. A photograph of the unit is shown in Fig. 4.

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Driven Telegraph-Telephony Transmitter Type S100A.

This transmitter comprises the driven telegraph set together with the modulator panel. When transmission of telephony is desired the link between terminals 3 and 4 on the telegraphy transmitter should be removed and the modulator panel connected up. The various telegraph-telephone switches should be put to the appropriate position. A simplified diagram of connections and a photograph of the complete transmitter are shown in Figs. 5 and 6.

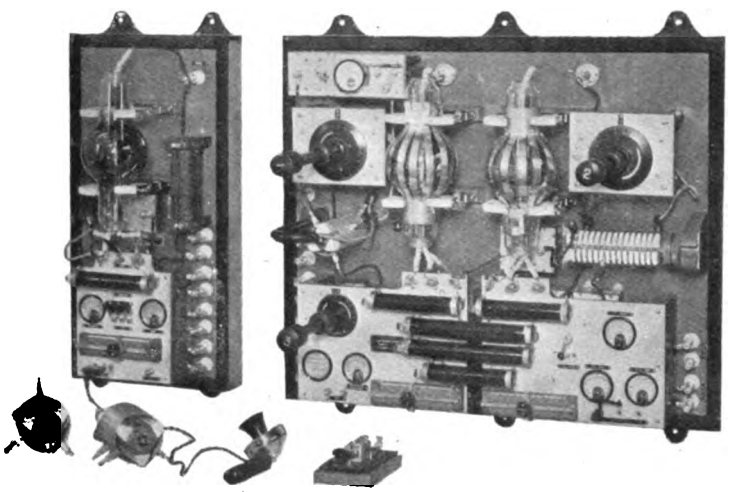

FIG. 6.

Valves.

Type MT12A valves are used throughout on the S100 series of transmitters. The filament voltage of these is 12.5 volts and the current taken by each is 5.5 amps. Copper shielding is placed over the valves as is usual on short wave sets in order to avoid unequal stress and consequent breakage of the valve.

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A MASTER OSCILLATOR OF HIGH CONSTANCY OF FREQUENCY

Oscillators of the valve capacity-inductance type, intended as primary drives for broadcast stations, have certain advantages over tuning fork and crystal drives, chief among which is the fact that such an oscillator can be made tunable over a wide range of frequencies so that the wavelength of the station it is desired to control can quickly be altered if necessary.

The valve oscillator described below is capable of very constant performance in spite of relatively large variations in temperature and voltage supply.

AS the number of Broadcast Stations in Europe is rapidly increasing, it has become necessary to take all possible precautions that each station shall remain on and operate on the frequency allotted to it, so that the greatest number of stations can be fitted into a fairly narrow band.

There are three well known schemes which are in operation in Europe in the attempt to keep stations to their particular frequency, these are, the tuning fork with valve drive and frequency doublers, the piezo electric oscillator, sometimes with frequency doublers and sometimes working on the fundamental frequency of the station, and finally the valve maintained condenser—inductance circuit.

Now both the tuning fork system and the piezo electric oscillator have a narrow frequency band; adjustable very largely by the temperature coefficient of the primary mechanical oscillator, and in the event of a general re-shuffle of International frequencies, the existing frequencies of these stations might cause a great deal of worry to the authorities in the re-setting of other frequencies so that the present steady frequency stations should not be disturbed. It might therefore be necessary to change these fixed frequencies, which would entail a fair amount of work and delay. Such being the case, the Marconi Company has considered it advisable to carry out some investigations with a view to producing a condenser—inductance circuit, as a primary oscillator, which circuit shall remain at great constancy of frequency during a period of daily operations, in spite of such troubles as gradually discharging batteries, and temperature changes. Also it is imperative that the master oscillator should be tunable over a wide range so that a new station could be adjusted to a frequency of such a value that it would not interfere with stations adjacent to it in frequency.

In the first place rigidity of construction was imperative, and secondly the behaviour of the materials under a fairly high temperature had to be investigated.

Some experience in the manufacture of low loss, small temperature coefficient, condensers and inductances was available, and this knowledge has been applied to the present problem.

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The question of maintaining the master oscillator at a fairly constant temperature called for an investigation into thermostatic control, lagging of the chamber, and heating.

Undoubtedly, an instrument such as the toluene regulator together with a stirring fan in the oscillator chamber, is one of the best methods of keeping such a chamber at a constant temperature throughout its bulk, but in a very large number

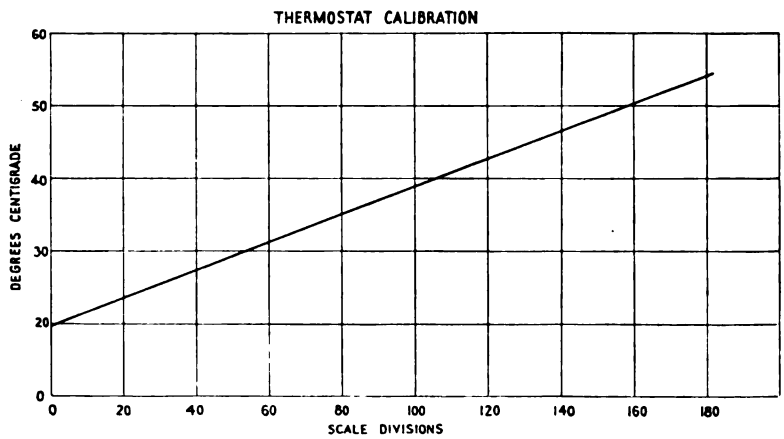

FIG. 1.

of cases this system is inconvenient, solely on account of the large amount of room required for the individual items comprising the whole regulator. Hence, it appeared necessary to reduce the regulator to the smallest dimensions, and the simplest form, and at the same time to avoid the use of a mechanical stirrer, and rely solely upon the convection currents set up by the heaters within the chamber.

The thermostat finally adopted is a simple bi-metal instrument and consists of a steel base at the ends of which are welded or brazed two small steel blocks. To these blocks are secured, by screwing, pinning and soldering a strip of metal of dissimilar temperature coefficient to that of the steel base, and this strip is " set " in a definite manner. At the centre of the strip is a platinum iridium contact and above the strip is mounted on an insulating bridge a contact screw with a platinum iridium point. A scale and pointer is provided on the thermostat so that the instrument can be adjusted to a temperature within the range. A typical calibration of such a thermostat is given in Fig. 1.

In conjunction with this thermostat is a heavy current relay for switching the main current of the heater system. This current is of the order of 1 amp. at 220 volts, and such a current would of course soon ruin the delicate contacts of the thermostat. The current actually handled by the thermostat is of the order of 100 milliamps

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at 6 volts which current operates the relay. This relay is a very simple affair, being an electro magnet with a light armature carrying a lever engaging with a spring controlled moveable contact arm. It is quite efficient and the certainty of action is due to the care with which the various dimensions of the moving parts were designed and to the provision of the various adjustments.

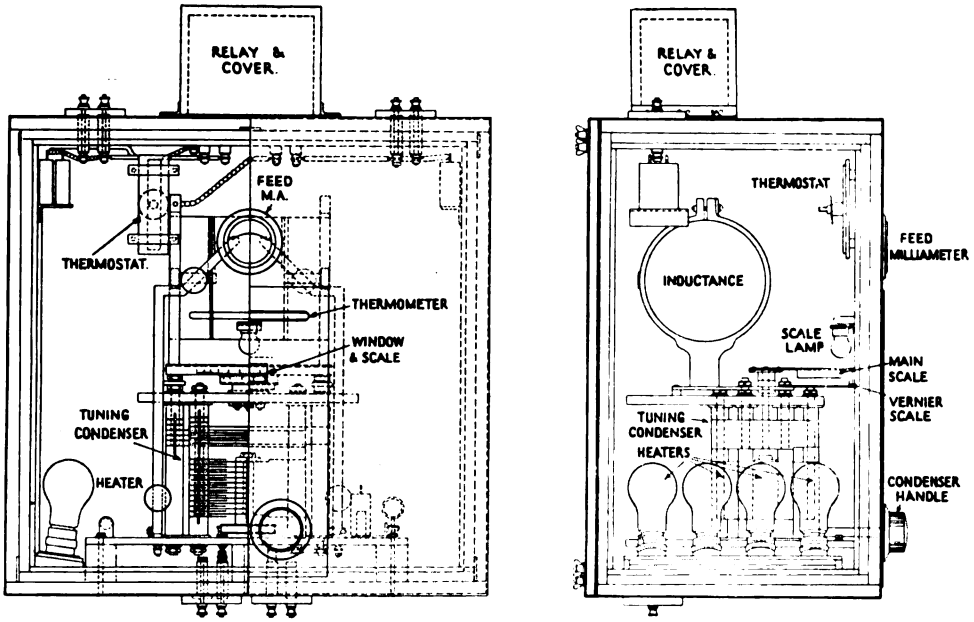

FIG. 2.

The heater consists of a bank of four lamps, which are placed in the lagged chamber at a position which was found to be the best for the maintenance of even heating throughout the system.

The chamber containing the Master oscillator is a stout wooden case, electrically screened by a copper covering on the outside, and heavily lagged on the inside surfaces. The back is entirely removeable so that inspection of the complete apparatus can be made when necessary. To avoid the necessity of removing the entire back to replace a burnt-out valve, a small hand hole closed by a lagged and screened cover is provided in the back.

Within the chamber is mounted the complete master oscillator, together with the thermostat and heaters. Suitable connections are brought through the walls of the chamber, and on the top is mounted the heavy current relay for switching the heaters.

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At the front of the chamber are the condenser adjusting handle, a thermometer, a window showing the scale and a feed milliammeter for the H.T. circuit.

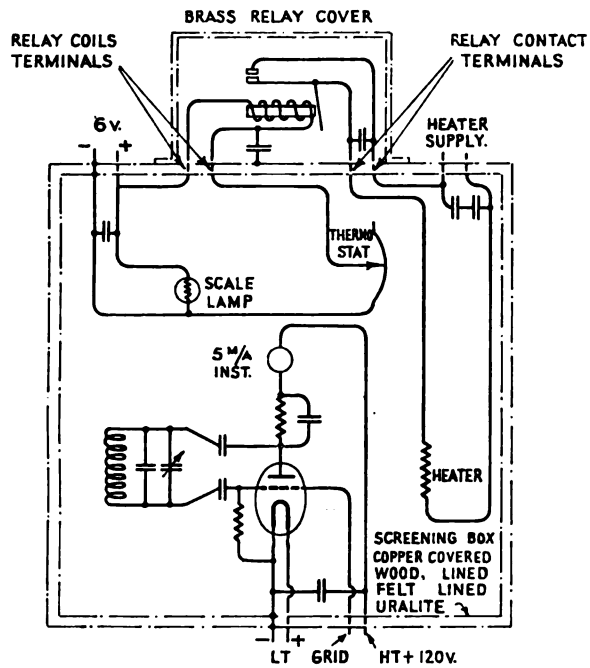

FIG. 3.

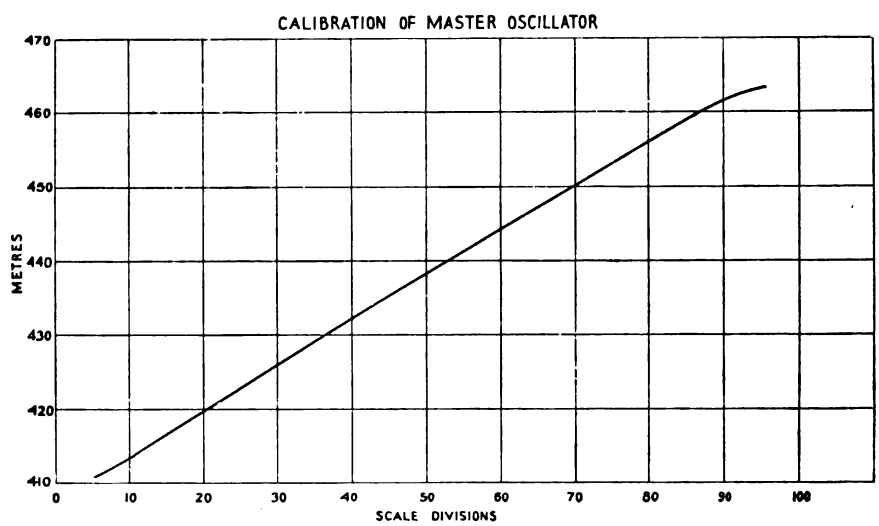

FIG. 4.

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The condenser used in this master oscillator is of the air dielectric "series" type. This condenser is a very stoutly constructed item and is similar in type but of different capacity to that described in a previous article on a Portable Precision Frequency meter. The insulating base of this condenser carries on its under surface various connections. On the upper surface are fixed such details as feed condensers, resistances and the valve.

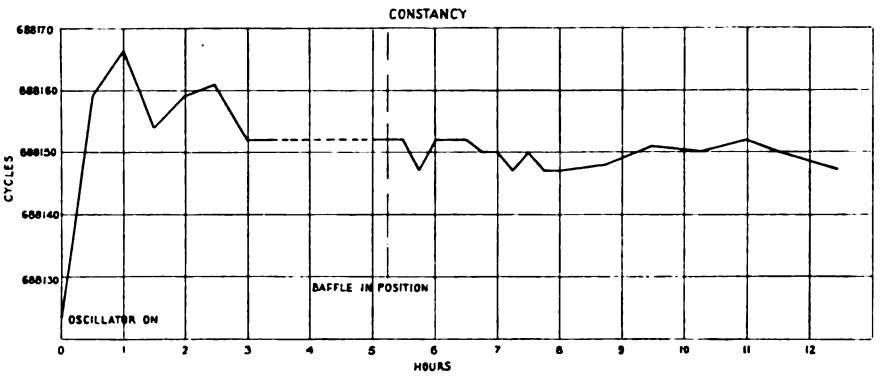

FIG. 5.

The vertical shaft of the condenser has fixed at its base a worm wheel which engages with a worm, the shaft of which is brought through the front of the lagged chamber and fitted with a handle.

On the insulated top plate of the condenser is fitted the inductance of the circuit and to the upper extremity of the condenser shaft is secured a brass sector upon the edge of which is engraved a scale. Beneath this scale is a vernier scale. On the main scale 100 divisions subtend an angle of 90°, and 9 divisions of the main scale are equal to 10 divisions of the vernier scale. The main scale rotates, whilst the vernier scale remains fixed. This permits of a very small window being cut in the screened lagged chamber and the disturbance of screening and lagging is thus reduced to a minimum. The scale and window are lighted by a small lamp connected to the L.T. battery of the valve circuit.

The inductance used is of copper wire wound on a porcelain former. Depending upon the total frequency band to be covered by the oscillator, so the size, type and number of the inductances vary.

For a short band a large porcelain tube can be permanently fixed to the instrument, but where a wide range must be covered, it has been found convenient to use smaller tubes and greater numbers. Fig. 2 gives a general idea of the chamber and the disposition of the various items included therein. This is typical of a narrow band master oscillator. The valve is at the back of the condenser and not shown.

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In Fig. 3 is given a typical diagram of connections for the master oscillator, scale lamp, thermostat, heater relay and heater. The values of the various components change to some extent with the frequency it is desired to generate and also with the number of ranges.

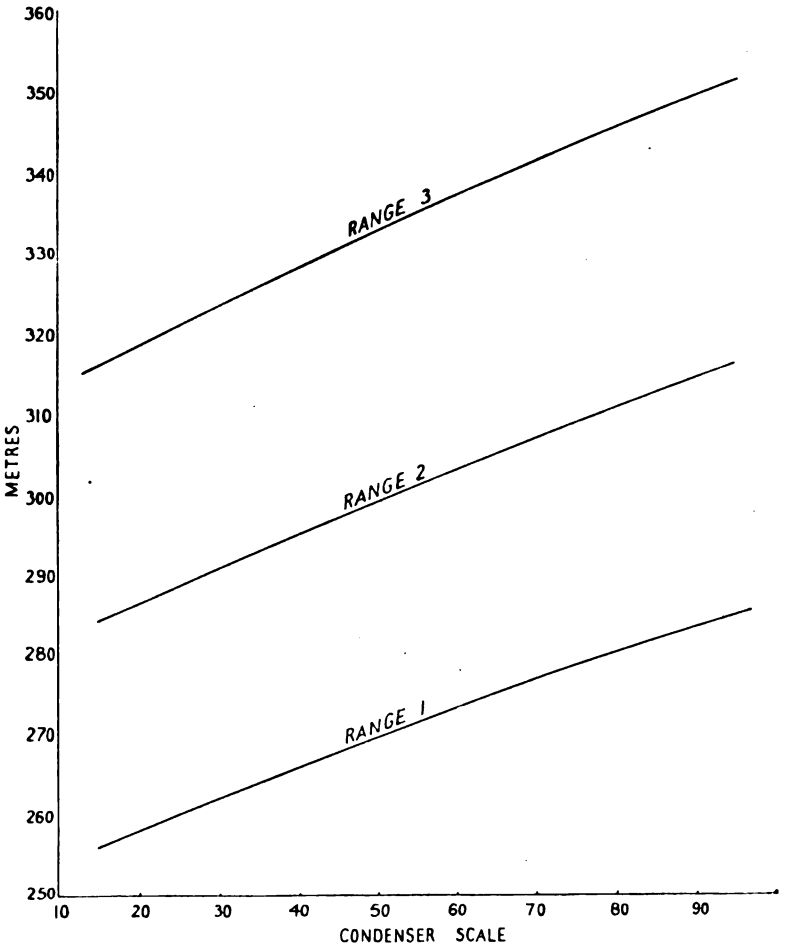

FIG. 6.

In practice it has been found desirable to arrange for the master oscillator to generate at half the frequency of transmission. From the master oscillator a suitable connection is taken to a frequency doubling circuit, and on by means of power amplifying circuit to the final circuit of the system.

A calibration of a narrow frequency band oscillator is given in Fig. 4. In this

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calibration the condenser scale is plotted against the output wavelength of the station. In this instrument a condenser change of 1 vernier division at 10 divisions and 1

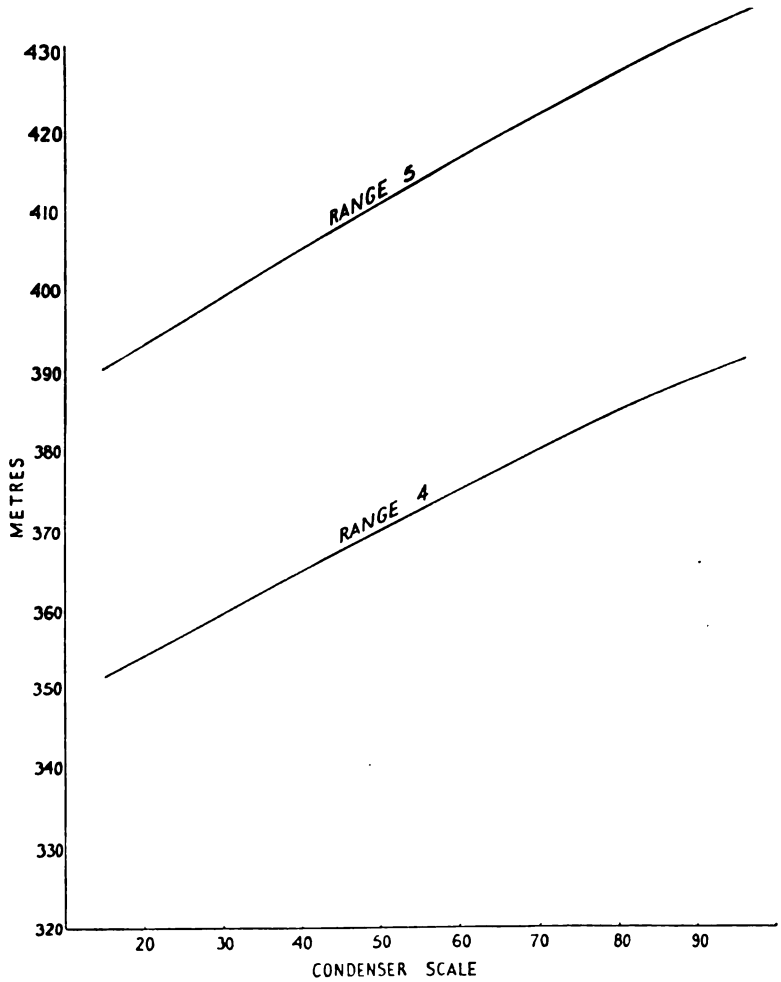

FIG. 7.

vernier division at 90 divisions of the condenser scale represents a change of final wavelength of 1 in 7,000 approx. at that point of the scale.

Fig. 5 shows the constancy of the master oscillator over a number of hours. It will be seen from this figure that a rapid change of frequency occurs at the beginning of the run, but as the temperature of the complete apparatus becomes uniform so greater steadiness is maintained. At a point in this figure is marked " Baffle in position." This refers to the insertion of a plate beneath the master oscillator unit

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to disperse an updraught of cool air and maintain the cooling of the apparatus at a more uniform rate. From that time to the end of the run, the stability of the frequency is indicated by the curve.

This figure gives the frequency as that of the final frequency of the complete apparatus.

It is of interest to note the changes of frequency due to changes of L.T. and H.T. voltages. These are given in the following table :—

	Volts.		Final	
	L.T.	H.T.	Freq.	Change.
Normal	6	119·2	688,186	
	6	119·2−5%	688,169	−1 in 41,000
	6	119·2+5%	688,198	+1 ,, 57,000
	6−5%	119·2	688,179	−1 ,, 95,000
	6+5%	119·2	688,186	No change.

These frequencies were measured by a valve maintained, constantly running, thermostatically controlled, tuning fork, as were all other frequencies given in this paper.

A change of valve of the same type was found to give a frequency variation of 1 in 95,000.

Figs. 6 and 7 show the calibration of a multi-range oscillator. In these figures the final wave length is plotted against the condenser valve and at the extremities it will be found that a condenser variation of 1 vernier division gives a change of wavelength of 1 in 8,000 approx. at the upper limit and 1 in 6,400 approx. at the lower limit.

Measurements have shown that the frequency variation in this multi-range instrument amounts to ± 9 cycles in 877,500 final frequency during a 6 hours run after the apparatus had been running with its thermostat for four hours.

Frequency changes due to voltage changes in the multi-range model are slightly worse than with the single range instrument, but in no case does a ± 5 per cent. change of L.T. or H.T. voltage cause a change of more than 1 in 27,000.

It will be appreciated that in a multi-range instrument, where the range change is made by a change of inductance, changes in the various inductances cannot be so completely compensated for with a single condenser as in the case of a single range instrument.

Finally, it may be mentioned that in the models described here, the heating current of the apparatus was alternating at 100 ∿ and from the local town service. Some trouble was experienced in this matter due to the breaking of the main heater circuit and the "hum" of the service, but this has been overcome by suitable shunting of contacts, relay coil and service supplies, and after considerable amplification the carrier wave of the system can be said to be unmodulated by the alternating supply.

T. D. PARKIN.

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MARCONI NAVAL RECEIVER

TYPE R.g.27

This receiver has been developed for use as a Naval Receiver covering a waveband of 150-3000 metres in 4 ranges. The design is such that overall efficiency and performance is maintained with minimum cost.

Its use will not of course be limited to Naval purposes, and it is anticipated that the demand for an inexpensive receiver covering this waveband will be met by the Type R.g.27 receiver.

THE R.g.27 receiver Fig. 1 consists of one screened grid high frequency amplifier coupled by means of a tuned anode circuit and condenser to a detector and followed by 2 low frequency amplifiers The first of these low frequency amplifiers is always in use, but switching is provided in order to obtain either aperiodic audio frequency amplification or tuned note filter amplification at 1,200 cycles. The second low frequency amplifier may be switched on or off at will and is a straight forward untuned transformer coupled amplifier. The detector is capable of self oscillation in order that reception of C.W. signals shall be possible. The aerial circuit is not tuned and the coupling arrangements to the first valve will be described later.

The wave range of the receiver is from 150-3,000 metres and is covered by 4 positions of the range switch.

The input circuit to the high frequency valve Fig. 2 is tuned by a condenser which is permanently ganged to the condenser tuning the detector grid circuit. This ganging effects a considerable simplification in the tuning of the receiver. The method of aerial coupling has been so designed that the ganging of the 2 tuned circuits is correct for a wide range of the electrical constants of the aerial, although the actual design is such that the 2 circuits are correctly ganged when the capacity introduced between the aerial and earth terminals of the receiver by the aerial is ·0002 mfd. Any aerial of from 40 to 100 ft. will give satisfactory results on this receiver, these figures referring to single wires sloping from the receiver at approximately 60°. A volume control in the form of a resistance in the screen grid valve filament circuit is incorporated in this receiver which has the effect of increasing either the selectivity or volume of the instrument. As the signal strength is reduced so the selectivity of the high frequency stage is increased. A double ended arrow engraved round the volume control knob is marked volume in one direction and selectivity in the other, and a compromise between these two factors can be obtained for any particular working conditions.

A voltmeter is provided in the circuit, reading up to 7·5 volts for filament voltage, and up to 150 volts to enable the H.T. supply volts to be checked.

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Valves.

Two alternative arrangements of valves can be adopted. In the first only 2 types of valves are needed, viz :—one 2-volt screened grid high frequency valve type S.215 and three type H.L.210 valves. A more usual arrangement consists of follow-

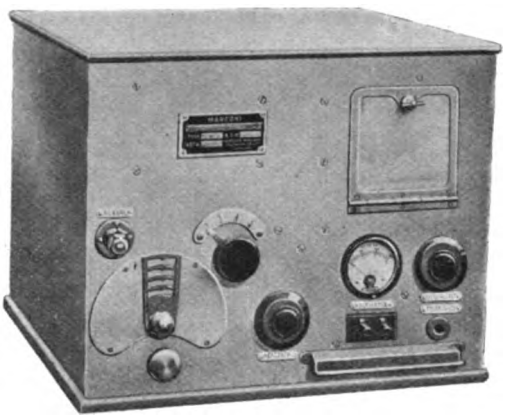

FIG. 1.

ing the S.215 high frequency amplifying valve by a DEH.210 valve as detector, and two DEL.210 valves as note magnifiers. When this latter arrangement is used greater output volume is obtained and to effect the change it is only necessary to

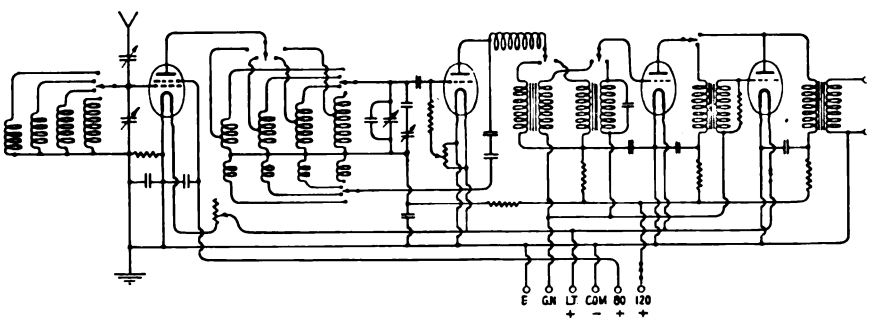

FIG. 2.

increase the grid negative on the low frequency valves. The grid bias, of ½ volt, to the high frequency valve is obtained from the filament battery so that no internal negative grid battery of special size is necessary.

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Accessibility has been treated as of prime importance and by undoing 4 finger screws it is possible to remove the set from its base which will normally be fixed by shock absorbers to the bulkhead. This removal at once exposes to inspection all switch contacts, variable condensers and low frequency components. Similarly by undoing finger screws the lid of the receiver can be removed giving full accessibility to the high frequency inductances, the connections between these, and the range switch and all valve holders.

In addition a simple method is provided whereby the panel carrying all valve holders and low frequency components may be detached from the instrument case giving complete accessibility to these components.

Valves can be inserted by removing the top lid of the receiver but a hinged drop door is also provided on the front panel for this purpose.

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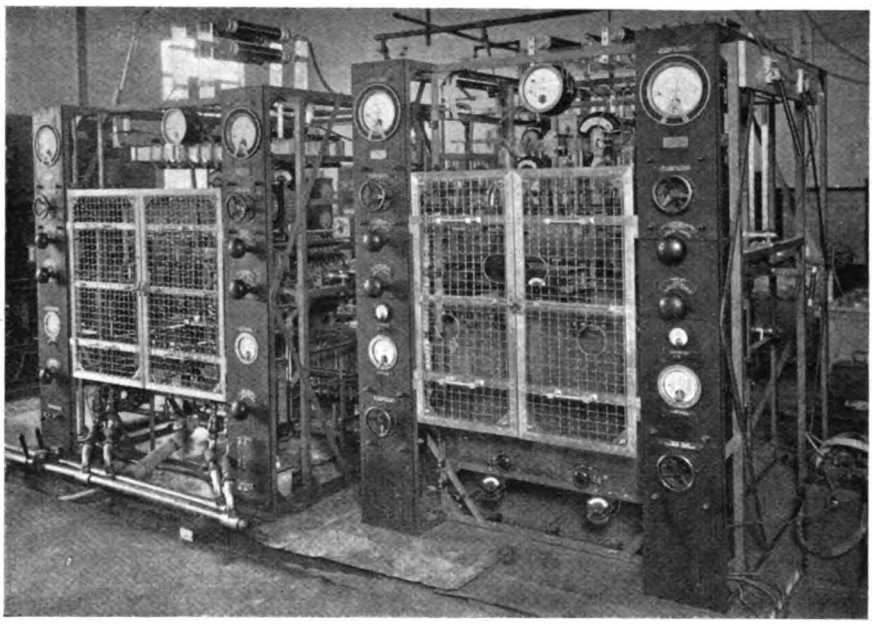
MARCONI NEWS AND NOTES

EMPIRE BROADCASTING

SIR JOHN SIMON'S SPEECH HEARD IN INDIA.



G5SW, the short-wave Empire broadcasting station at Chelmsford. This photograph shows the main and No. 2 magnifiers.

The possibilities and importance of Empire Broadcasting could not have been more strikingly indicated than they were recently when Sir John Simon speaking from London through 5 SW, the B.B.C. short wave experimental broadcasting station at the Marconi Works at Chelmsford, was able to address the people of India on Indian affairs at a time when the Report of the Committee of which he was chairman was engrossing the attention of all classes in India. Every word he said is reported as having been clearly heard, and brought home very vividly the service that broadcasting may render to the Empire in times when matters of imperial importance are under discussion, and more particularly at any time of crisis.

5 SW at Chelmsford has rendered good service to British broadcasting and the Empire on many previous occasions when special broadcasts from England have been relayed for the benefit of audiences overseas ; and reports on the excellence of its

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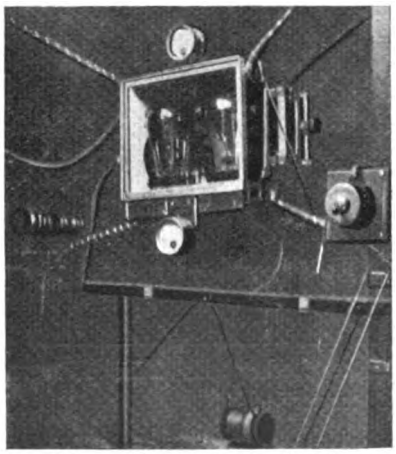
transmission have been received from places as far apart as China and Peru in addition to South Africa, India, Australia and many European countries where 5 SW has a regular and enthusiastic audience.

Some of the most important occasions on which it has been used were in the transmission to the Empire of the Thanksgiving Service in Westminster Abbey for the King's recovery, and the speeches made by the King and principal national delegates at the opening of the London Naval Conference this year.

Wireless and the "Southern Cross."

Major Kingsford Smith's success in flying across the Atlantic is a triumph for wireless organisation, as he has pointed out in every message he has written concerning his experience.



Marconi apparatus in the "Southern Cross."

Like those other prudent adventurers Captain Courtney and Major Franco, Major Kingsford Smith was firmly of the opinion that pioneer flights of this kind can only be justified in so far as they add something definite to human knowledge as well as to human achievement. This he has done, for in addition to his success, the wise and thorough organisation of his flight has enabled him to put forward the definite theory that the unreliability of the compass in the neighbourhood of Newfoundland, where visual sights are bad, is the cause of the tragic failure of other gallant airmen who have essayed this perilous voyage insufficiently equipped. He has also supplied valuable knowledge as to the conditions to be expected on this particular air route.

Wireless direction finding justified itself long ago as a navigational instrument for ships at sea and commercial aeroplanes, and in Major Kingsford Smith's flight it has established itself as a vital necessity in any well organised long distance pioneer flight. As Major Kingsford Smith said, "But for the wonderful wireless we should never have got out of the fog," and the lessons they brought with them out of that great ordeal would not have been, as they are now, at the service of every airman who may attempt the Atlantic flight in future.

A Last Minute Decision.

When Major Kingsford Smith arrived in England to prepare for his flight to the United States he was equipped with only short wave wireless apparatus. While

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The " Southern Cross."

this was extremely useful for keeping him in communication with wireless receiving stations on either side of the Atlantic over long distances it was not adapted to the transmission of signals for the purpose of communication with ships and coast stations and for direction finding, for which instruments working on longer wavelengths are necessary. It was decided, therefore, to complete his equipment by installing a Marconi wireless transmitter working on wavelengths of 600 and 800 metres.

This last minute decision proved the determining factor in his safe arrival in the United States, owing to the fact that it was entirely due to his ability to communicate with ships and coast stations and to receive bearings calculated from signals sent out by the Marconi instrument that he was able to find his way to land through the dense fog that enveloped him as he was approaching Newfoundland. With this installation, he states, he was in constant communication with ships throughout the flight.

Telegram to the Marconi Company.

One of the first things Major Kingsford Smith did on arriving at New York was to send the following telegram to the Marconi Company :—

> Marconi Company, London.
>
> Was altogether delighted at perfection of Marconi Wireless instrument and the tremendous service it rendered me. It was put in at the shortest notice yet it performed excellently and was vital to the success of our flight. Most enthusiastic and delighted with it. Best regards.
>
> (Signed) KINGSFORD SMITH.

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Delegates to the Empire Press Conference at the Somerton Beam station. Mr. T. Dunbabin (Australia) is speaking to Marchese Marconi on his yacht "Elettra," off Genoa. Admiral of the Fleet Lord Wester Wemyss is on the speaker's left.

Major Kingsford Smith's experience is similar to that of Captain Courtney whose rescue, after he came down in the Atlantic in his attempt to fly to the United States, was due to his having carried a Marconi wireless installation ; and of Major Franco, the well-known Spanish airman who relied on a Marconi wireless installation in his successful flight across the South Atlantic from Spain to South America.

These experiences, and the disasters which have overcome intrepid flyers who have attempted to cross the Atlantic without wireless equipment, demonstrate, as Major Kingsford Smith, Major Franco and Captain Courtney have all asserted, that no long-distance ocean flights should be undertaken without adequate wireless equipment.

Press Delegates Visit Beam Stations.

One of the most interesting functions associated with the recent Empire Press Conference in London, which was attended by journalists from all parts of the British Empire, was the visit paid by a number of the delegates to the Marconi short wave Beam transmitting and receiving stations of Imperial and International Communications Limited at Dorchester and Somerton.

While the delegates were at the Somerton station they had the novel experience of talking with Marchese Marconi who spoke from his yacht " Elettra " off Genoa, 1000 miles away.

The telephone conversation had been arranged so that Marchese Marconi could offer a welcome to the visitors. Messages were first exchanged between the yacht

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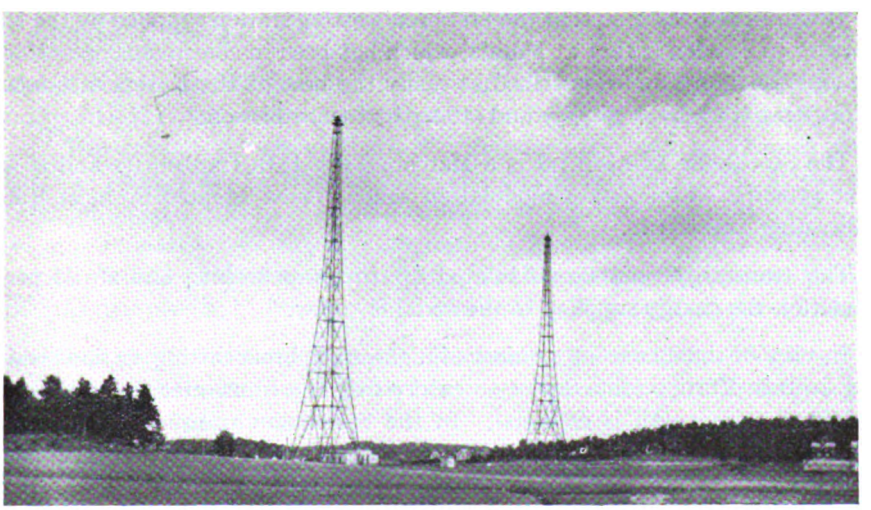
and Admiral of the Fleet Lord Wester Wemyss, and then the company, some of whom listened through headphones while others assembled around a loud-speaker, heard Marchese Marconi explain that while he was a long way from Somerton he was glad that radio-telephony afforded him a rather novel opportunity of greeting members of the Empire Press Conference together with some of his own fellow directors.

Sir Augusto Bartolo, of Malta, expressed the thanks of the delegates and had a conversation in Italian with Italian journalists on board the "Elettra."

Importance of Communications.

During the sessions of the Empire Press Conference, some of the most closely followed discussions were on the subject of communications, one of the speakers being Sir Basil P. Blackett, K.C.B., K.C.S.I., Chairman of Imperial and International Communications Limited, and consequently the delegates showed keen interest in the operating details of the Beam stations.

The Rt. Hon. Lord Wester Wemyss, G.C.B., Director of Marconi's Wireless Telegraph Co., Ltd. and of Imperial and International Communications Limited speaking at a luncheon to the delegates of the importance of communications, said that he thought they would see to what extent these had progressed and how much further they hoped to get in an organisation by which they hoped to increase the happy relations which existed within the Empire.



Marconi 60 kilowatt broadcasting station, at Spanga, near Stockholm.

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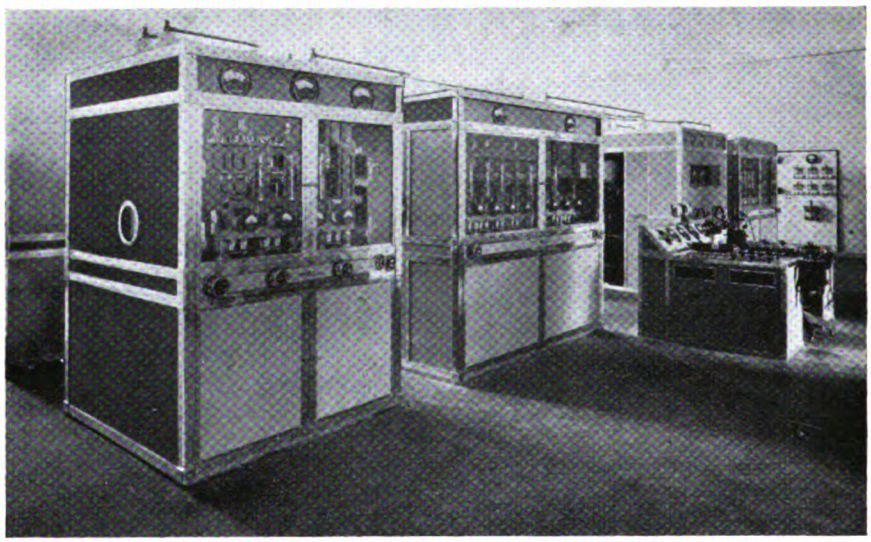

Marconi 60 kilowatt broadcasting station at Spanga, Sweden : view of transmitter panels.

New Swedish High Power Broadcasting Station.

The second high-power broadcasting station to be supplied by the Marconi Company to Sweden has now been put into operation at Spanga, about 12 miles from Stockholm.

It will be remembered that the first broadcasting station supplied by the Marconi Company to Sweden is that at Motala, which has been in continuous operation since 1927 and which has been described as easily the best of the European Continental broadcasting stations in quality and strength of transmission.

The Stockholm transmitter is a Marconi Type P.B. transmitter and is worked on the principal of low power modulation which is now adopted by most European broadcasting authorities.

The transmitter can be modulated up to 100 per cent., and at 80 per cent. modulation the energy supplied to the aerial is 50 kw.

In view of the increasing number of high-power broadcasting stations which are being built in Europe some device to ensure that the transmitter adheres rigidly to its allotted wavelength is essential. In the Stockholm transmitter this has been achieved by providing a thermostatically controlled valve drive which has been developed with great success in the Marconi Research laboratories.

The Stockholm transmitter operates on a wavelength of 436 metres.

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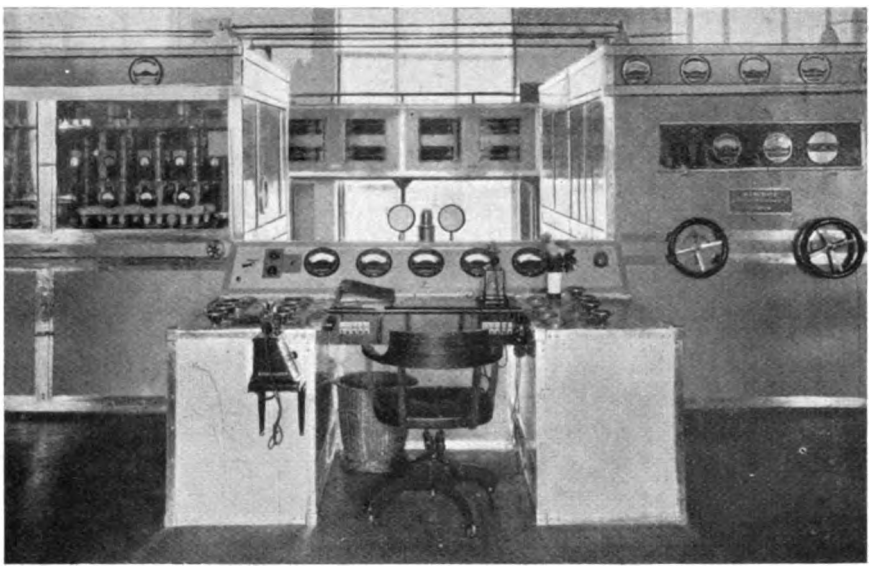

Marconi 60 kilowatt broadcasting station at Spanga, Sweden: transmitter panels, control table and harmonic filter.

Marconi Aircraft Apparatus on Test.

A working demonstration of the well known Marconi Type A.D.6h aircraft wireless equipment was recently given at Croydon Aerodrome to certain distinguished foreign military representatives.

One set of this type was installed in the Marconi Company's Bristol Fighter, and a second set in a D.H.50, which was chartered from Imperial Airways Limited for the purpose. The ground station with which communication was maintained during the tests was erected at the Marconi Company's experimental section at the aerodrome and consisted of a Marconi aircraft transmitter Type A.D.18a (which has a total input of approximately 350 watts, or approximately one-tenth of the power of the Croydon Aerodrome wireless transmitter) and a receiver of approximately the same sensitivity as that used at Croydon. The aerial employed had a height of only 30 feet.

The two aircraft left the aerodrome simultaneously, the Bristol Fighter flying along a direct line between Croydon and Leamington, and the D.H.50 along a direct line joining Croydon and Lincoln.

Two-way telephonic communication was maintained between the two aircraft, on their diverging courses, as far as possible, after which the Bristol Fighter returned to the aerodrome and the D.H.50 continued until the limits of ground-to-air and air-

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to-ground telephonic and telegraphic ranges were reached, test messages being passed at pre-arranged points.

Ranges Obtained.

The results obtained, which are given below, are interesting as showing the ranges which are easily obtainable in actual practice, and in spite of severe interference which was experienced on the wavelength allotted for these tests.

With the Type A.D. 6h equipment. :—

Inter-aircraft telephony range.	28 miles
Air-to-ground telephony range.	107 miles
Air-to-ground telegraphy range (interrupted continuous waves)	136 miles
Air-to-ground telegraphy range (continuous waves)	200 miles
Ground-to-air telephony range	55 miles
Ground-to-air telegraphy range (interrupted continuous waves)	107 miles
Ground-to-air telegraphy range (continuous waves)	147 miles

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THE MARCONI REVIEW

August, 1930

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THE MARCONI REVIEW

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Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

RADIATION FROM A SHORT WAVE VERTICAL AERIAL

The question of the distribution of radiation from vertical aerials is of extreme importance in many short wave problems.

In the following article the effect of the earth on the vertical polar diagram and of the radiation efficiency of a short wave vertical aerial is discussed, and a practical method is given of obtaining a figure for the radiation efficiency of such an aerial.

Energy Losses.

THE polar radiation diagrams of vertical short wave aerials have recently been worked out by the writer, Journal I.E.E., Vol. 65, No. 366, June, 1927, by M. J. O. Strutt, Annalen der Physik 1929, 5 Folge Band, Heft 6, and by W. Howard-Wise, Bell Technical Journal, October, 1929, Vol. 8, No. 4.

These investigations all agree in the final formula which shows that at great distances there is no horizontal radiation and that the remaining radiation energy distribution is a pure polar diagram in as much as the energy radiated over any two hemispheres is the same. Thus in Fig. 1 the energy radiated over A and B is the same if A and B are at a sufficient distance from the Transmitter T, but this is not true of C if C is sufficiently close to T. The difference is, of course, the energy radiated through C and lost in the ground between C and A.

The whole of this energy has to be supplied to the aerial and the question arises what fraction of the total energy supplied to the aerial remains in the final polar diagram after the earth has taken its quota.

This may be calculated as follows if we know the distribution of electric and magnetic forces over the surface of the earth. Let T be the transmitter, Fig. 2, and S be a hemisphere at such a distance from T that the pure polar diagram is wholly established.

Then the whole of the energy supplied to T is radiated through the closed surface surrounding T consisting of the hemisphere S and the part of the plane of the earth

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covered by the hemisphere. The part of the energy radiated through the earths surface may be considered as lost, and the radiation efficiency, so to speak, of the aerial is the ratio of the power radiated through S, which is usefully employed, to the sum of this and the energy radiated through the earth's surface or rather wasted in the earth's surface.

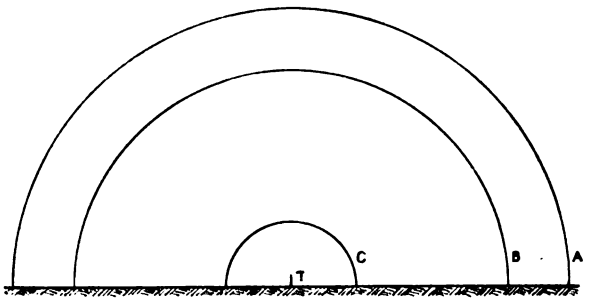

FIG. 1.

This radiation efficiency may be determined semi-experimentally if the total resistance of the aerial can be measured.

For the total power supplied to the aerial is as before stated partly radiated through S and partly wasted in the earth's surface.

Now the amount radiated through S may be easily found. It is only necessary to calculate the final polar diagram and to integrate this to obtain the useful power radiated from the aerial and hence the useful radiation resistance r say.

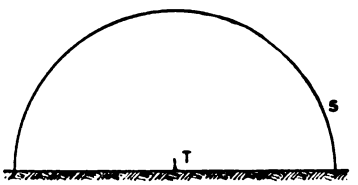

FIG. 2.

This polar diagram can now be calculated from the aerial disposition and earth constants as indicated in the first paragraph.

If the total resistance can be measured, the radiation efficiency is the ratio of r to the total measured resistance R. This method has been applied to the calculation of the radiation efficiency of a $\frac{1}{2}$ wave aerial placed just above the earth's surface as shown in Fig. 2.

In the first place we have to calculate r, which depends on the radiation polar diagram of this aerial.

An element dx at a height x above the earth's surface will produce a field

$$dF = \cos\theta \left(e^{-i\phi} + \frac{n\alpha - n^1}{n\alpha + n^1} \cdot e^{+i\phi} \right) I_0 \sin \frac{2\pi x}{\lambda} dx$$

Where $\phi = \dfrac{2\pi x \sin\theta}{\lambda}$

Where $n = \sin\theta$

$$n^1 = \sqrt{\sin^2\theta + \epsilon - 1 + 2i\sigma\lambda c}$$

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$\alpha = \epsilon + 2i\sigma\lambda c$

ϵ = Earth Inductivity

σ = ,, Conductivity

λ = Wave length

c = Velocity of light

$\frac{n\alpha - n^1}{n\alpha + n^1} = R_0$ the reflection coefficient of the earth for the angle of elevation θ

The total electric field is therefore proportional to

$$\int dF = F = I_0 \operatorname{Cos}\theta \int_0^h \left\{ e^{-i\phi} + \left(\frac{n\alpha - n^1}{n\alpha + n^1}\right) e^{+i\phi} \right\} \operatorname{Sin}\frac{2\pi x}{\lambda}\, dx$$

after some reduction this integral may be put in the form (suitable for computation)

$$F \propto \operatorname{Cos}\theta \frac{I_0\lambda}{4\pi} \left\{ \left[\frac{2(\operatorname{Cos}\zeta(1 + \operatorname{Sin}\theta) - 1)}{1 + \operatorname{Sin}\theta} + \frac{2[\operatorname{Cos}\zeta(1 - \operatorname{Sin}\theta) - 1)]}{1 - \operatorname{Sin}\theta} \right] + (R_0 - 1) \left[\frac{e^{-i\zeta(1 - \operatorname{Sin}\theta)} - 1}{1 - \operatorname{Sin}\theta} + \frac{e^{-\zeta(1 + \operatorname{Sin}\theta)} - 1}{1 + \operatorname{Sin}\theta} \right] \right\}$$

for a perfect conductor $R_0 = 1$ and the last term vanishes.

The first term therefore represents the polar diagram for a perfect conductor and the second gives the correction for imperfect conductivity.

Fig. 5 curve B gives the results of the computation for

$$\alpha = \frac{\lambda}{2} \qquad \sigma = \frac{1}{2 \times 10^{12}} \qquad \epsilon = 2 \qquad \lambda = 22m$$

Curve A is the polar diagram for perfectly conducting earth.

Now the radiation resistance corresponding to A has been calculated by Stuart Ballantine, who found it to be 103 ohms.

Hence $\frac{2}{103}$ = ratio of area enclosed by B to that of A, from which we find r = 31 ohms.

Measurement of Total Resistance of $\frac{1}{2}\lambda$ aerial.

The short wave signal measuring apparatus has been used to determine the resistance.

The method used may be explained with reference to Fig. 4.

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A current was introduced into the circuit under test Z (part of the circuit A B C) through the calibrated mutual M which is part of the signal measuring set. The circuit A B C was loosely coupled to a sensitive receiver and the output of this recorded at D.

Let M be the value of M required to give a certain measurable output ; then the EMF in A B C is proportional to M, now let a known resistance R be inserted in series with Z. The output will be reduced. M_1 is now increased to M_2 to give the same output reading as before. The current i in A B C is therefore the same in both cases.

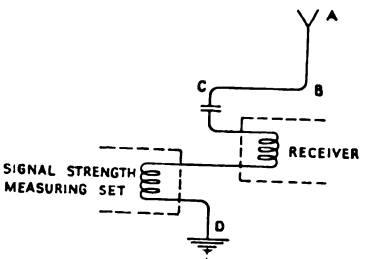

FIG. 3.

Now $i_1 \propto \frac{M_1}{Z}$ $\quad i_2 \propto \frac{M_2}{Z+R}$

$$\frac{M_1}{Z} = \frac{M_2}{Z+R}$$

so that $$\frac{Z+R}{Z} = 1 + \frac{R}{Z} = \frac{M_2}{M_1}$$

and $$Z = \frac{R}{\frac{M_2}{M_1} - 1}$$

from which the impedance Z can be obtained. If the circuit under test is tuned $Z = R_1$ the resistance of this circuit, so that $R_1 = \frac{R}{\frac{M_2}{M_1} - 1}$

In the tests the aerial arrangement was as follows. Fig. 3. AB was a vertical stretch of wire 10.5M. approximately which tuned to 21M. wave.

BCD was a ¼ wave tail at about 1M. above the earth's surface. The added resistance was inserted at R (Fig. 4) and it was assumed that the reflection points in the system were insufficient to make any appreciable difference in the current at R and that in the centre of the stretch AB. DBC was first tuned to ¼ and measured ; it was 15 ohms. After preliminary testing the correct length for DB was found, and when connected at B the total resistance was found to be 179.5 ohms. (The mean of several readings.)

The resistance method was checked by measuring a known resistance of 54 ohms, the measured mean was 56.25.

The effective resistance of the aerial AB itself is therefore approximately 165

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ohms and the radiation efficiency

$$\frac{31}{165} = 18.8\ \%$$

This means that only 18.8 % of the power supplied to the aerial is usefully employed for long distance communication.

This is a surprising small value, and depends to a certain extent on the assumed values of the earth's inductivity and conductivity. No reasonable alteration of these would materially effect the results, and we may feel confident therefore that in the particular case measured the radiation efficiency is only of the order of 20 %. Some doubt as to the generality of this result may be entertained. It is possible for instance that there were large local dielectric losses in the wooden masts and support to the measured resistance. A theoretical calculation of the power wasted in the earth is therefore of value as a check.

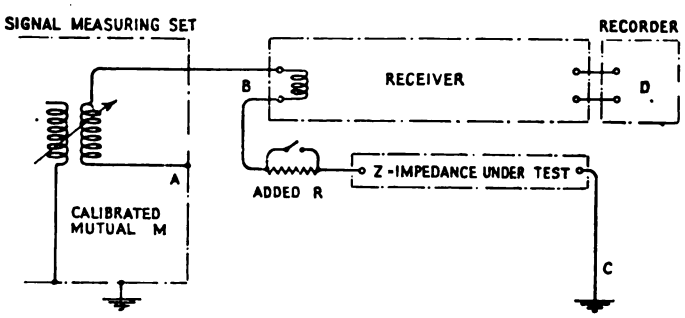

FIG. 4.

Sommerfeld's analysis serves as a starting point for the theoretical analysis.

Two methods may be employed.

The first is to calculate the electric and magnetic forces at the surface of the earth, form the product $\frac{I}{4\pi} E_\lambda H_\alpha$ and integrate this over the surface of the earth.

This represents the earth loss from which a corresponding resistance may be obtained, R_ϵ say, then the total resistance of the aerial will be $R\epsilon + r$ (r defined as before) and the radiation efficiency will be $\frac{r}{R_\epsilon + r}$. There is a certain amount of doubt as to whether Sommerfeld's analysis represents the electromagnetic forces accurately up to the neighbourhood of the transmitter and this must await a more rigorous analysis but the calculation will at least give an approximate value for the loss R_ϵ. The second method also based on Sommerfeld's theory has already been used to calculate the resistance of a $\frac{1}{2}\lambda$ aerial in the broadcast range.

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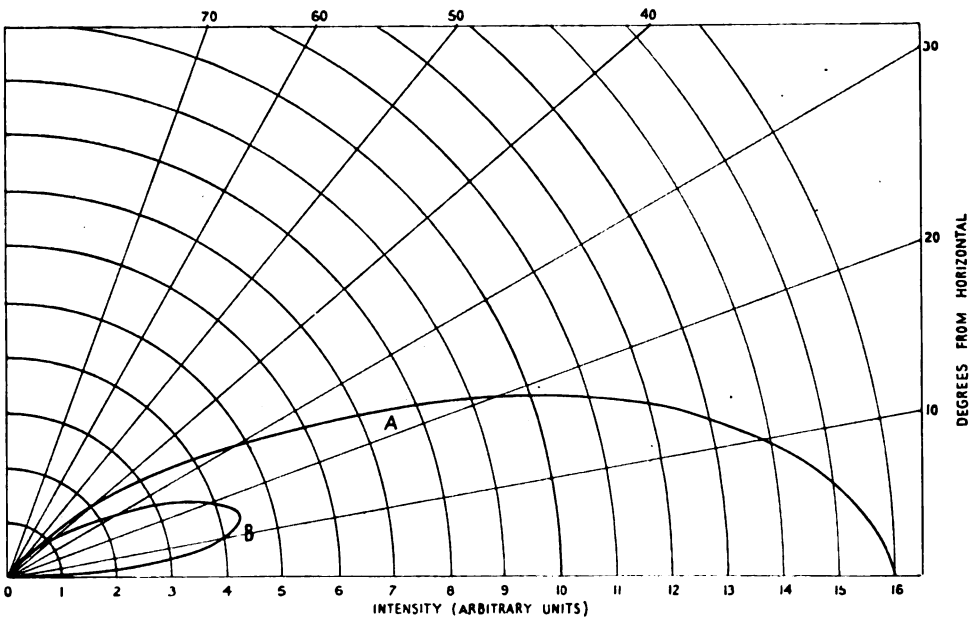
It consists essentially in calculating the electric and magnetic forces at or near the surface of the aerial and determining in essence the total radiation from the aerial. The value of this method is that it indicates that the resistance over and above that of a $\frac{1}{2}\lambda$ aerial on a perfectly conducting plane increases practically in proportion to the square root of the frequency. Now accurate measurements of this difference have been made on a 288M. wave and it is found to be 12 ohms. If this is increased in the ratio of the square roots of the frequency a value of 45 ohms is obtained for the added R and the total resistance in the 21M. case is $103 + 45 = 148$ which though less than the measured 165 is sufficient to indicate that the measured resistance is a representative value. A recent measurement of a $\frac{1}{2}\lambda$ aerial gives a value for this of 180 ohms.)



The analysis of the first method is not yet complete but preliminary computation shows that the earth loss is a considerable proportion of the total resistance and thus confirms the measured results which show low radiation efficiency. One result of importance emerges which can be stated without carrying out the full integration. It is that the earth loss decreases with the height of the aerial above the ground.

The expression for the earth loss varies as

$$e^{-j\frac{4\pi h}{\lambda}} \cdot \frac{1}{(1 + \epsilon + 2i\sigma\lambda c)^{\frac{1}{2}}}$$

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Where h = height of aerial above the earth.

λ = wave length.

ϵ = specific inductive capacity of earth.

σ = conductivity of earth.

c = velocity of light or approximately

$$e^{-\frac{2\pi h}{\lambda}\sqrt{\frac{1}{\sigma\lambda c}}}$$

and taking $\lambda = 30$, $\sigma = \frac{1}{2 \times 10^{12}}$

this becomes $$e^{-\frac{h}{\lambda}0{\cdot}662}$$

To reduce the loss to one-tenth of its surface value, the aerial must be raised to 3.5 wave lengths above the surface of the earth. With the earths resistivity increased tenfold the necessary height is 1.1 λ so that in practice between 1 and 3 wave lengths height is necessary to obtain good radiation efficiency.

Further confirmation of these results is obtained from certain transmission tests.

In the first place there are the results published in the writer's "Short Wave Telegraphy" Journal I.E.E., Vol. 65, No. 366, June 1927. These show that the effect of raising a $\frac{1}{2}$ wave doublet from just above the earth's surface to a height of about 80 M. results in a quite appreciable gain in the signals received in Sydney on a 15M. wave. The average gain was of the order of 10T.U. This is rather more than might be expected. Part of the gain may be attributed to the fact that not only does raising the aerial increase the total radiation efficiency but also improves the low angle radiation which is required for long distance transmission.

Recently some rough signal measurements have been made on the short wave band.

As the result of a years interception of signals at Broomfield, Chelmsford, the attenuation suffered by the rays on various short wave lengths is now fairly accurately known, the path of the rays having also been disclosed by facsimile measurements.

With this data it should be possible to calculate approximately the signal strength if the radiated power is known. Or we can work backwards and calculate radiated power. In nearly every case this calculated power is a small fraction of the nominal power of the station. These results therefore suggest that in general the radiation efficiency is small.

T. L. ECKERSLEY.

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THE MARCONI SPEECH CONTROL EQUIPMENTS FOR BROADCASTING

The term Speech Control Equipment is intended to cover the whole chain of apparatus between the Microphone proper and the input terminals of one or more Broadcast Transmitters, its function being to repeat to the transmitter a faithful and distortionless copy of the currents generated in the microphone at a power level sufficiently high fully to modulate the transmitter.

In this sense speech input or speech control equipment includes a consideration of the microphone and the studio, the various amplifiers and their associated monitoring and quality checking devices, frequency correction equipment, and a study of the interconnecting lines and cables.

Modern broadcasting technique shews an increasing tendency to group various transmitters into national or even international networks with the result that a growing proportion of the total programme material is transmitted from cultural centres by landwire and radiated from distant transmitters.

It is obviously necessary to ensure that these programmes are equal to or have a near approach to the fidelity of transmission obtainable on local circuits and this again depends on the speech control equipments and lines.

The Engineers of the Marconi Company have made a special study of the many problems involved and have designed and developed the complete series of equipments now to be described.

THE simplest possible equipment is the case of one programme from one studio radiated by one local transmitter. The essential parts of the equipment are clearly shewn in the schematic line diagram, Fig. 1.

Speech currents generated in the Microphone are amplified by the Microphone Amplifier (A) and the Control Amplifier (B) is used to increase the power level to the degree required by the transmitter. Auxiliary apparatus in the form of a modulation indicator gives a continuous check on the degree of modulation, and a monitoring or check receiver and loud speaker for checking the quality are shewn in the diagram.

Standard Equipment

An elaboration of the simple equipment as shewn in Fig. 2 is a very useful group and is, in fact, the equipment standardised for supply to all normal broadcast studios. Two microphones and one gramophone pick-up are shewn, but several alternative arrangements are possible; for example three microphones or one microphone and two gramophones and all three inputs may be faded and mixed together.

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The B Amplifier has also a triple input circuit with Fading Potentiometers and such extraneous effects as time signals, etc., may be superimposed on the main programme by their use.

Outside Broadcast

When it is desired to radiate items of interest from places outside the studios, an " outside broadcast equipment " is necessary, which is connected to the Standard Speech Equipment as shown in Fig. 3.

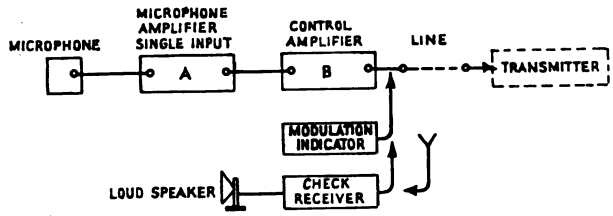

FIG. 1.

The outside broadcast may take the form of an operatic performance, an orchestral concert, religious service or dance music, and the provision of a triple input circuit to the portable A Amplifier enables several microphones to be disposed in the auditorium, the combined output being mixed to obtain a satisfactory balance of the various performers or speakers.

Transmitter Equipment

In the simple equipments so far considered it has been assumed that the transmitter was sufficiently near to the control centre for the connecting lines to be neglected. If this is not the case an additional B Amplifier may be necessary at the Transmitting Station. A further study of the quantitive aspect will be made in a later paragraph.

In all cases it is of course advisable to have suitable control and monitoring facilities at the transmitter, but where the line is long it is frequently also desirable to instal a local testing and emergency studio.

The equipment shewn diagrammatically in Fig. 4 has been developed for this purpose, and it will be seen that it is substantially similar to the simple studio equipment of Fig. 1. Actually the difference is that studio equipments have a polished hardwood table or desk for convenience of the seated control operator, whereas the transmitter equipment, being only for occasional use, is not so equipped.

It is usually recommended that an equipment as shewn in Fig. 4 be installed at the transmitter even where additional magnification is not essential, as the large reserve of amplification gives a good margin of safety and the test studio facilities are available in case of failure of the landlines from the main studios.

Simultaneous Broadcast

It is frequently required in broadcast schemes to connect a number of regional transmitters to a common national or sometimes international network and to radiate items or programmes from any or all of the transmitters simultaneously. The main control room them becomes a kind of nerve centre for the system and a

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more complex speech control equipment becomes necessary, the actual complexity depending of course on the scope of the scheme.

Obviously it is impossible to deal with the many combinations that may be required, and each particular proposal must be studied on its own merits, but in order to demonstrate a typical case, a hypothetical simultaneous broadcast network has been set out in Fig. 5.

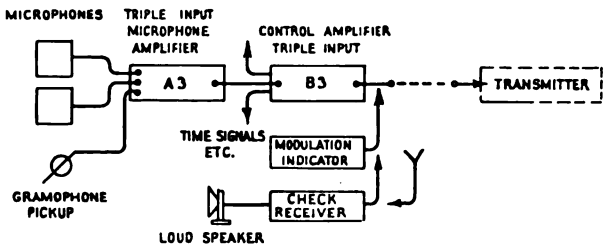

FIG. 2.

The control centre is shewn connected to two local transmitters X and W by short landlines and to three distant regional transmitters by long trunk lines. International trunk lines connecting to neighbouring countries are also shewn. Let it be supposed that the following programme arrangements are required at some particular time :—

(A) A dramatic play originated at the central studio is to be radiated simultaneously from the local transmitter X, the short wave transmitter W and the distant regional transmitter Z.

(B) An educational talk is to be broadcast from regional station Y only, the talk being given by a professor in the central studio.

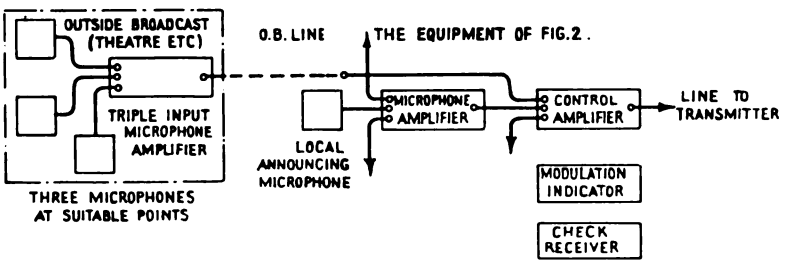

FIG. 3.

(C) A programme received from a neighbouring country is to be amplified, corrected for line distortion and re-transmitted over a second trunk line to regional transmitter V.

(D) During the time that the programmes as outlined are in progress a time signal from an observatory is to be radiated from all stations, and the play is to be interrupted at another time for an important speech or other outside broadcast.

The set-up necessary at the control centre for such a scheme is shewn in diagrammatic form in Fig. 6.

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It should be noted that the rather elaborate interconnecting and line switchgear has been omitted as it would tend to obscure the diagram.

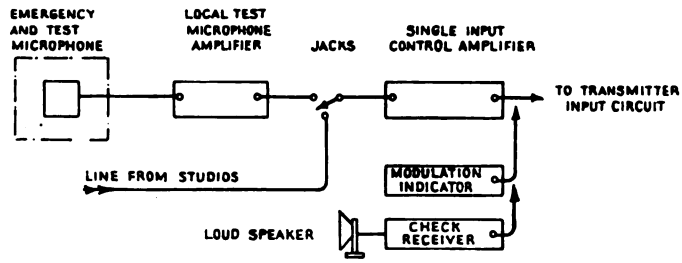

FIG. 4.

The dramatic play microphones are connected to amplifier A2, and control amplifier B1. The distribution unit D enables up to three separate circuits to be loaded in a single B amplifier without destroying the balance of circuit impedances, and divides the outgoing signal to its three channels X, W and Z. Attenuator networks ensure that the load put on the amplifier by varying lines is substantially constant. In the case of X and W the lines are short and the programme goes direct, but as Z is supposed to be a long line it is assumed to be necessary to correct the frequency characteristic by means of the equaliser network EQ1 and to compensate for the equaliser losses by means of the line or level raising amplifier C1. The important outside broadcast which is to interrupt the play is shewn connected to the second input circuit of the B1 amplifier, ready to be faded up when the time arrives.

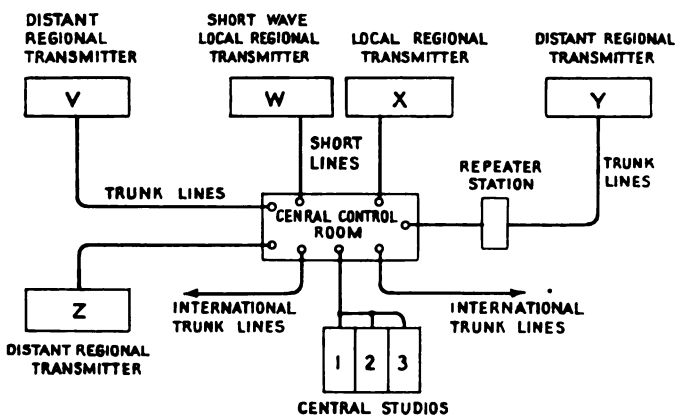

FIG. 5.

Connected to the third B1 input and also to all the other outgoing circuits is shewn the time signal oscillator with its direct observatory line.

The professor gives his talk in studio 3 which is connected to the line outgoing to transmitter Y by amplifiers A3 and B2, equaliser EQ2 and level raising amplifier C2.

The international trunk line simply connects through C3 amplifier and distributing unit and equaliser EQ3 to the outgoing V line. As an indication of the physical arrangement of an equipment such as has been described, Fig. 7 shews a photograph of a typical assembly.

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Power Levels

Modern types of Marconi broadcast transmitters, for example Types P.A.13 and P.B.2 have been standardised so that a peak input signal voltage of 3·5 volts will fully modulate the transmitter.

The input circuit is a transformer of 600 ohms primary impedance, this figure having been selected to match the average line impedance.

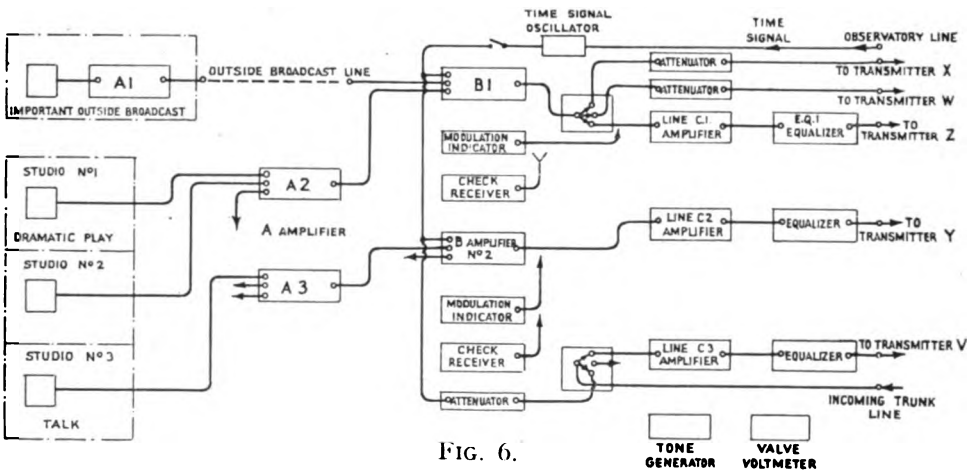

FIG. 6.

The peak power level required therefore, at the input terminals of the transmitter is 10 milliwatts. In the following consideration of the power levels of the various circuits, all levels are related as a certain number of decibels or transmission units above or below 10 milliwatts, which power is called zero or datum level.

The standard testing frequency is 1,000 cycles.

Table I. gives the approximate power levels and gains or losses of the various items of the equipment, the figures being chosen as typical figures and not representing the utmost limits of the apparatus.

TABLE I.

TYPICAL POWER DISTRIBUTIONS IN DECIBELS.

(ZERO LEVEL 10 MILLIWATTS).

Apparatus.	Normal Maximum Output Level.	Normal Maximum Gain.	Average Loss.
Marconi Reisz Microphone..	—50/—70	—	—
A Amplifier	—10	+40	—
B Amplifier	+ 5	+45	—
C Amplifier	+10	+35	—
Equaliser	—	—	—5/—20
Distribution Unit	—	—	—5/—10

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The normal power level distribution to be expected in a typical case of simple broadcast from a local studio is shewn in Fig. 8.

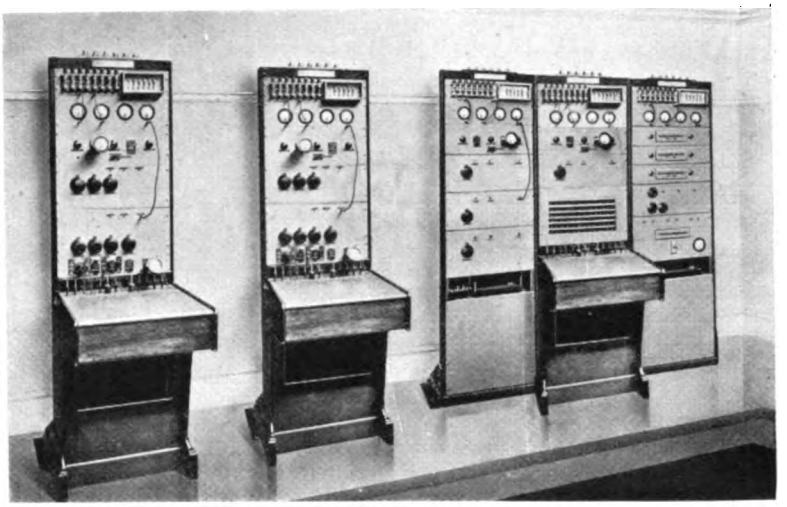

FIG. 7.

An allowance of 5 decibels has been made between the A and B amplifiers to cover switchboard and cord losses and the permissible loss in the transmitter landline is 5 decibels. With an outside broadcast the average levels change as shewn in Fig. 9.

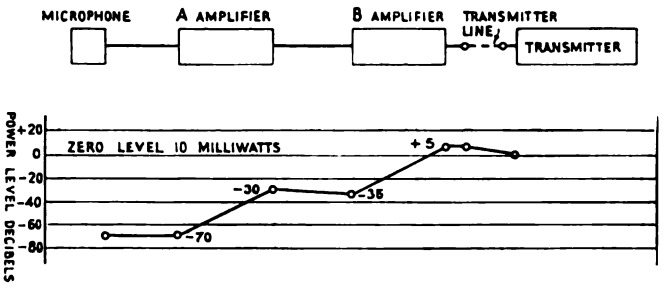

FIG. 8.

The losses in the outside broadcast line have here to be considered, and 5 decibels is given as an average case for a permanently erected line.

In practice a temporarily installed line might give considerably more loss than 5d.b., but it will be noticed that the B amplifier is working comfortably within its maximum gain and could compensate for a much greater loss in the O.B. line.

Considerations of noise level and cross talk, however, make it undesirable to work with too feeble a signal on the line and it is unwise to allow the level to drop much below—25. The third condition shewn in Fig. 10 obtains in simultaneous broadcasting where the line between the central control and one of the distant transmitters is a long trunk.

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Simultaneous Broadcast Levels

It is assumed that the above diagram shews only one circuit of a fairly complex system and two distribution units (D) are shewn, each giving a loss of 10 decibels.

The trunk line has a loss of 20 decibels at its corrected level, a further 15 decibels being lost in the correcting network or equaliser (EQ).

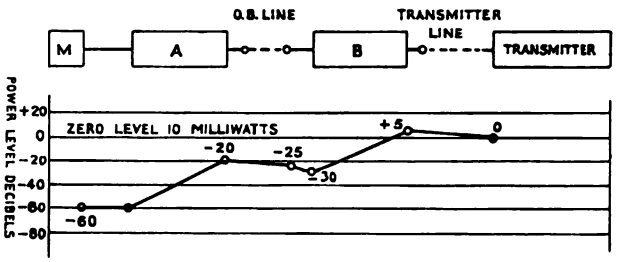

FIG. 9.

Restrictions of Line Input Level

In certain countries the Post Office or the particular authority controlling the use of telegraph or telephone lines for broadcasting will not allow a signal above a stated level to be put on its lines. For example, in England the British Broadcasting Corporation is officially restricted to an input of 3·5 milliwatts R.M.S. or—4·4 decibels.

This level corresponds with the average peaky mixture of speech and music to a peak value of the order of +2 or +3 decibels. The normal line input level in this paper has been taken as 5 decibels peak so that if a limit is imposed it will be necessary to reconsider a particular case.

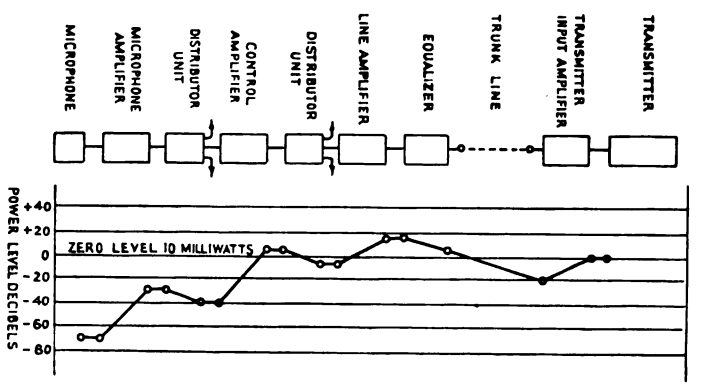

FIG. 10.

In general, however, there is a sufficient margin of safety in all the equipment to work with the lower level.

Landlines and Cables

The landlines or cables used to transmit broadcast music and speech present a very important part of the input circuits.

It is often the case that existing lines must be used for high quality broadcasting even though they be poor ones, but where it is possible to erect special lines or cables the following short study will give an indication of the results to be expected.

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Many of the same conditions apply to broadcast lines as apply to ordinary telephone lines, that is to say, a good telephone line is a good broadcast line in so far as freedom from noise and extraneous inductions, insulation, etc., is concerned, but whereas quite intelligible speech is possible on a telephone line having a frequency cut off at 2,500 cycles, for broadcasting the whole band between 30 and 10,000 cycles is required in an ideal case.

Overhead Air Lines

Heavy gauge overhead lines have usually a good frequency characteristic, but an increasingly large proportion of the longer lines are being put underground so that it is generally difficult to use air lines.

Where special overhead air lines can be run for connecting a broadcast studio and transmitter, they are recommended to be erected as follows :—

The conductors should be of bare copper spaced at least 12 inches (30 cms.) apart and supported on stout poles so that the lowest wire is at least 12 feet (4 metres) from ground.

The poles should be spaced about 80 yards (75 metres) apart, depending of course on local circumstances, and the conductors should be transposed at each fifth pole with symmetrical twist. It is recommended that at least four pairs of conductors should be run on each route to ensure spare lines and service wires.

Table II. gives some of the chief characteristics of various sizes of conductors and also the attenuation in decibels per mile loop at 1,000 cycles.

TABLE II.

CHARACTERISTICS OF AIR LINES.

Conductor.	Diameter M/M.	Resistance Ohms.	Capacity Mfds.	Attenuation d.b. per mile loop.	Miles loop per d.b.
40 lbs. Bronze ..	1·2	91	·0075	0·355	2·8
100 lbs. Copper ..	2	17·6	·0081	0·14	8·8
200 lbs. ,, ..	3	8·8	·0086	0·065	15·3
400 lbs. ,, ..	4	4·4	·0092	0·036	27·4

It will be noticed that for a permissible drop of 5 decibels the theoretical distance between the studio and transmitter varies from 14 miles for the 40 lbs. bronze line to 137 miles for the 400 lbs. copper line.

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In practice, however, the theoretical attenuation is considerably exceeded due to leaky insulators, damp atmospheric conditions, etc., and also the cut off of the higher frequencies becomes very pronounced with long lines, so that the practical limits (without amplification or correction) are :—

For the 40 lbs. bronze line	3 miles.
For the 100 lbs. copper line	12 miles.
For the 200 lbs. copper line	25 miles.
For the 400 lbs. copper line	50 miles.

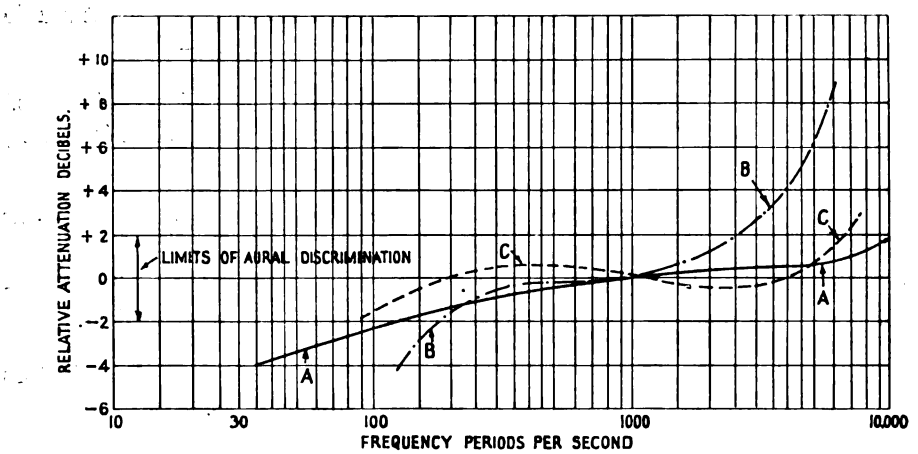

FIG. 11.

Underground Cables

Buried cable has the considerable practical advantage over air line in that it is not affected by blizzards or storms, but for broadcasting it requires considerably more care in selection.

The chief difficulties are, first that the high capacity and small core size give frequency cut off at quite a low point and a high attenuation, and secondly as the cable is usually run in the form of a multicore cable, much trouble may be experienced in selecting a reasonably quiet pair, free from cross talk and induction from the other circuits in the cable. Table III. gives a list for underground cables of similar characteristics to those for air lines in Table II.

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TABLE III.

CHARACTERISTICS OF AIR SPACED PAPER CORE CABLES.

Conductor.	Diameter. M/M.	Resistance. Ohms.	Capacity. Mfds.	Attenuation d.b. per mile loop.	Miles loop per d.b.
6½ lbs.	0·5	270·7	·065	2	0·5
10 lbs.	0·7	176·0	·065	1·56	0·64
20 lbs.	0·9	88·0	·065	1·1	0·91
40 lbs.	1·2	44·0	·065	0·76	1·32

It is apparent from the Table that the permissible run for 5 decibels loss is much less than with air lines. Although the cables are not affected by climate, considerations of frequency distortion prevent in practice the theoretical lengths being attained so that the practical limits of distance for cables between the studio and transmitter (as before, without correction or additional amplification) are :—

For 6½ lbs. cable, ... 1 mile.
For 10 lbs. cable, ... 1·5 miles.
For 20 lbs. cable, ... 2·5 miles.
For 40 lbs. cable, ... 4 miles.

Special Broadcast Cables for High Quality

Where a special line must be run for broadcast purposes, and where the relatively cheap overhead lines, either because of climatic conditions or æsthetic considerations are not permissible, a specially made broadcast cable is strongly recommended.

Such a cable is laid up with air spaced paper insulated cores, the separate pairs being screened with one or more wrappings of metallized paper.

The cable is lightly Pupinized or loaded with series inductance coils at points about 1 kilometre apart and gives an extremely good frequency characteristic, the cut off frequency being higher than 10,000 cycles.

The attenuation for cross talk between separate pairs is greater than 100 decibels so that with the levels used for the broadcast no interference is caused by induction from other circuits.

A characteristic frequency distortion curve of such a cable 20 kilometres long is given in Fig. 11 (Curve A).

It is interesting to compare this curve with that of an ordinary cable of the same length (Curve B) and the same cable when corrected with equalizing networks (Curve C). See Fig. 11).

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Repeater Stations

When the trunk line to a distant transmitter is very long, it becomes necessary to raise the level of the signal at one or more intermediate points by means of a repeater station, and also to insert intermediate correction networks.

The type of one way repeater station used for this purpose consists in its essential parts of a C amplifier for raising the level of the signal to compensate for the attenuation of the incoming line section and of the equalizer used for correcting the characteristics of the outgoing line section. Generally speaking a repeater will be necessary if the attenuation of the line exceeds 20 decibels, and where a number of repeaters are necessary, it is generally satisfactory to instal a repeater for each 10 decibels loss. This gives a comfortable margin for correction and for exceptionally noisy sections.

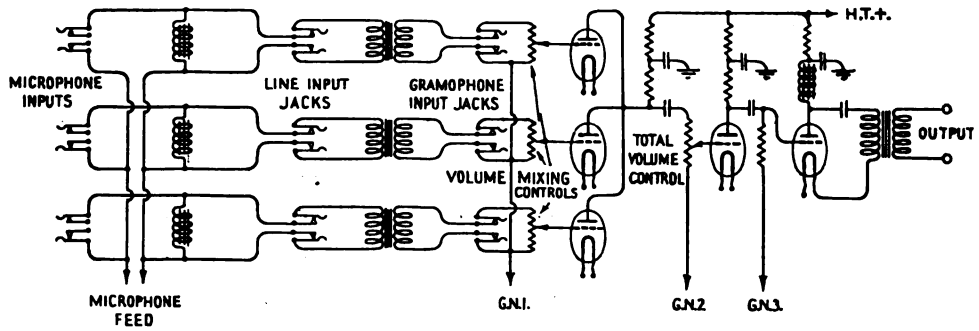

FIG. 12.

If frequency correction is necessary a further loss of anything up to 15 decibels will be occasioned by the network and the repeating amplifier must therefore have a gain of at least 25 decibels. The C amplifier has a gain of 35 decibels and is therefore ample for the purpose.

When a repeater is installed a 1,000 cycle generator is usually provided for adjusting the levels and correcting the lines, the whole equipment being mounted in a standard rack. It is obviously economical and convenient to group repeater stations at existing test points or broadcast control centres where this can be done, and also to run several trunks through the same point, as these arrangements enable common batteries, testing equipment, etc., to be used for all lines.

Layout and Design of the Equipments

All the equipments described are arranged for mounting vertically in steel racks of standard bay width. The amplifiers are supported on vertical brass panels with screening covers fitted in easily accessible positions on the back of each panel. The general finish of all the parts is the standard Marconi cellulose grey enamel, giving a uniform and satisfactory appearance.

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The arrangement in racks gives an exceptionally easy control and unlimited flexibility. It is quite a simple matter to extend an existing equipment when desired either by adding additional bays to the racks or by adding additional units to spaces in existing bays.

Battery busbars and connecting leads are all located in uniform position at the top of the racks and neat cables cleated to the channels carry the battery leads to their respective points.

Assemblies of Unit Parts

All the equipments are assembled from a combination of the Units listed below :—

1. The Marconi Reisz Microphone.
2. The Microphone Amplifier (A Amplifier).
3. The Control Amplifier (B Amplifier).
4. The Line Amplifier (C Amplifier).
5. The Modulation Indicator.
6. The Equaliser.
7. The Check or Monitoring Receiver.
8. The Distribution Unit.
9. The Low Frequency Variable Tone Generator.
10. The Valve Voltmeter and 1,000 cycle Generator.
11. The Metering Panels and Control Desk.
12. The Line Control Switchboard.

1. The Marconi Reisz Microphone

This high quality microphone which has been standardised by broadcast authorities all over the world, is fully described in Pamphlet 238, on pages 24 and 25.

2. The Microphone Amplifier (A Amplifier)

The relatively small output from the microphone is amplified to a power level as previously discussed, of about one-tenth of one milliwatt by means of the three stage microphone amplifier.

The amplifier has three stages, resistance-capacity coupled, and each anode circuit is isolated from the common battery by means of decoupling resistances and condensers. Special attention has been given to the problems of microphonic noises and the amplifier is substantially free from trouble in this respect.

Three models are standardised, a rack mounting model with single input, for one microphone, a triple input rack model for three microphones, and a portable

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model for outside broadcast in a travelling case. Each input circuit of each model is arranged with three jacks, so that the input impedance conditions can be arranged :—

(A) For a Reisz Microphone.

(B) For a high impedance source primarily intended for high impedance gramophone pick-ups.

(C) For a low impedance source suitable for emergency landline use, or a suitable low impedance pick-up, or a special microphone circuit.

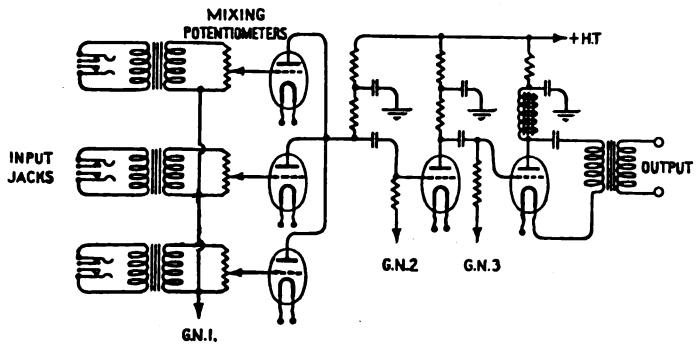

FIG. 13.

The circuits are automatically matched by the insertion of the correct plug. The triple input model thus has nine separate and distinct input circuits, in groups of three. Each group is connected to a special fading potentiometer to control the volume, so that three separate programmes can be faded or mixed together in any desired proportions. The potentiometer controls are arranged so that the volume can be faded up or down with an entire absence of clicks.

The output circuit of the rack models is arranged to match the impedance of the input to the B amplifier. The portable model for outside broadcast has a transformer output matching the impedance of an average line. When used with the normal battery equipment the A amplifier has a maximum gain of 40 decibels and an undistorted power output of 50 milliwatts.

The frequency characteristic is substantially linear from 30/10,000 cycles. Fig. 12 gives a diagram of connections of the triple input A amplifier.

3. The Control Amplifier (B Amplifier)

The purpose of the B amplifier is to accept the output from the A amplifier or from a line and to magnify the signal to the final level required by the transmitter line or transmitter input circuits.

The amplifier is three stage resistance coupled and is substantially similar to the A amplifier except that it is capable of dealing with much higher power levels.

A single input and triple input model have been standardised, the single input

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circuit being suitable for direct connection to the " A " output, and the triple input model having in addition two 600 ohm line inputs for outside broadcast.

The inputs are equipped with fading potentiometers and the three inputs of the triple model can be mixed together as in the case of the A amplifier.

A simplified schematic diagram is given in Fig. 13.

The amplifier, when used with normal battery equipment gives a gain of about 45 decibels and is capable of a completely undistorted power output of 60 milliwatts. If distortion of 5 per cent. is allowed this output can be increased to 500 milliwatts. By changing the output valve and increasing the battery voltage these levels can be substantially increased. The frequency characteristic is substantially linear between 30 and 10,000 cycles.

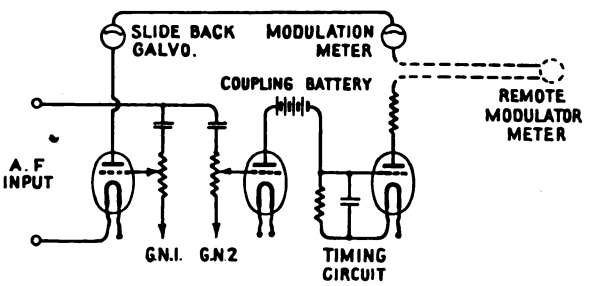

FIG. 14.

4. The C. or Line Amplifier

The Line Amplifier, used for compensating for line losses caused either by a long line or by correcting equalisers, is a two stage resistance capacity coupled amplifier with transformer input and output to suit the average lines.

The connections are similar to the B amplifier, except of course for the fact that it has only one output, one volume control and two valves.

The normal main of the C amplifier is about 35 decibels and the undistorted power output is of the order of 250 milliwatts, depending upon the type of output valve used and the battery voltages, which are arranged to suit any particular case.

The amplifier is substantially linear in frequency characteristic between 30 and 10,000 cycles.

5. Modulation Indicator

The modulation indicator is necessary on a speech control equipment in order that the general level of the programme may be kept within the limits of the transmitter modulation and " blasting " prevented.

The circuit used consists essentially of a linear rectifier valve coupled through a battery and timing circuit to a reversing valve with a comparatively heavy anode feed.

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In the anode circuit of the second valve is an indicating instrument calibrated in percentage modulation. A condenser-resistance timing circuit having a quick charging period and slow discharging period enables the device to respond quickly to the peaks of modulation. The return action is slow enough for the peaks to be read and the peak conditions to be continuously observed. A third valve is also included which functions as a " slide back " or valve voltmeter. The indicating meter in the anode circuit of the third valve is normally steady at zero, but any peak modulation over a certain predetermined limit will be indicated on the scale. A special feature of the modulation indicator is that provision is made for the connection of a large meter with 6 inch scale which can be mounted in any position desired. The scale of this instrument is also marked in percentage modulation.

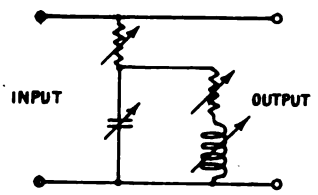

FIG. 15.

6. Equaliser

The equaliser or line correction unit consists essentially of a combination of variable inductance, variable capacity and variable resistance which can be connected to the input of a line in order to modify its frequency characteristic in any desired manner. The simplest and perhaps most generally used equaliser circuit is shown in Fig. 15, but the instrument is arranged so that more complex circuits using both shunt and series arms can be employed when required.

7. Check Receiver

The Check Receiver or monitoring amplifier is used for observing the quality of the signal radiated by means of a moving coil loud speaker. Its circuit consists of a low sensitivity tuning circuit and radio frequency detector coupled to a two stage high quality L.F. amplifier.

Arrangements are made so that the amplifier can be used separately to observe the quality of the signals at any point of the speech control system, or alternatively, with the detector to observe the quality of the radiated signal by wireless. When the check receiver is supplied at a studio, the radio frequency pick-up is by a short outside aerial, but at the transmitter a small inside aerial is used.

A schematic diagram is shewn in Fig. 16.

8. Distribution Unit

The Distribution Unit is used in simultaneous broadcasting when the output of the B amplifier is required to feed more than one circuit at the same time. It comprises an arrangement of jacks and resistances so that the insertion of any number of loads on the output side can be effected without disturbing the total load of the unit as a whole.

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A schematic diagram is shewn in Fig. 17.

The resistances R are made equivalent to the load they replace when the plugs are withdrawn, so that the total load on the input circuit is always constant.

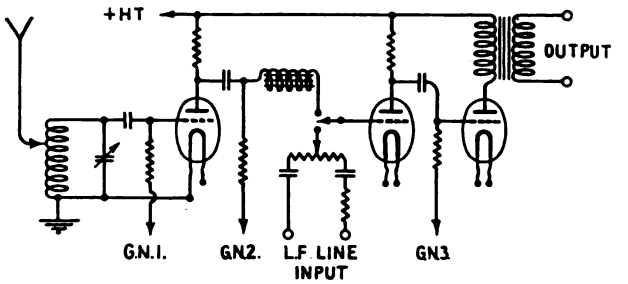

FIG. 16.

9. Low Frequency Tone Generator

The low frequency tone generator is required when taking frequency characteristics of apparatus and lines.

The electrical circuits were fully described in the March Number of the MARCONI REVIEW.

10. Valve Voltmeter and 1,000 Cycle Generator

The circuits of this instrument which is also required for use in line measurements, were fully described in the abovementioned issue of this journal.

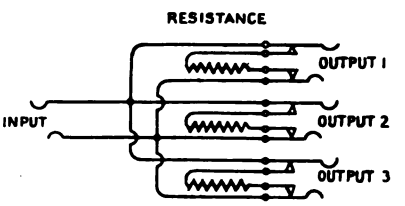

FIG. 17.

11. Metering Panels and Control Desk

At the top of each rack is mounted a narrow panel with all the necessary battery switches and fuses for service on the particular rack.

Below the switch panel is a similar panel containing all necessary indicating meters for the power circuits of the particular rack.

All racks intended for use at a control centre to which studios are attached, have hardwood desks on the power part, to form a convenient table for the seated operator.

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Above the control desk are the plugs and cords for inter-connecting the various circuits, and the modulation indicator may be taken from its normal position and plugged in at table height if desired for greater convenience in control.

12. Line Switchboards

The simple equipments are each provided with a jack strip and cord shelf for dealing with the lines and inter-connections. Although the apparatus has been so designed that the necessary inter-connections can be carried out without the use of an external switchboard, in the larger simultaneous broadcast schemes it is sometimes better to use a separate central control board to avoid the necessity of walking from rack to rack when inter-connecting. Such a switchboard obviously calls for special treatment on the merits of the particular case considered, and no standard has been developed.

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A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—IV

PART I.—THE PHASE OF CARRIER TO SIDE BANDS AND ITS RELATION TO A SYNCHRONOUS FADING PHENOMENON

In a previous paper, "A Study of Wave Synthesis by Mechanical Means," an investigation of the effect of the phase shift of carrier to side bands was made for the case of a 100% sine modulated carrier. From this investigation it appeared that small shifts of carrier phase resulted in considerable signal distortion, a phase shift of the order of 90° created distortion taking the form of frequency doubling and a phase shift of 180° reversed the signal. The particular case chosen, however, was not really representative of the majority of the modulated waves used in practice for two reasons :—*

(1) *In practice the percentage modulation rarely approaches 100%.*

(2) *The signal wave is seldom a pure sine wave in character.*

With a view to getting a better idea of what is happening, a further investigation by mechanical means has been made with waves having shallow modulation and using signal envelopes both of a pure tone and having a complex shape.

WHEN dealing with a group of waves having different frequencies it is necessary to understand clearly the meaning of phase relationship. One can only talk about phase relationship between waves of different frequencies at some point of reference and in the particular case under discussion this is the phase of carrier at the instant of time when the side band waves are in phase opposition ; such a point of reference in the case of a sine modulated wave indicates the commencement of the signal envelope. Thus in Fig. 5 vector C represents the carrier and vectors S^1 S^2 represent the side bands and this group of vectors is rotating at high frequency in an anti-clockwise direction C at the carrier frequency, S^1 losing on C and S^2 gaining by an equal amount. The moment represented indicates the maximum value of the high frequency cycle, in this case equal to the carrier maximum alone (since the other two cancel) that is, it depicts the condition as at " x " Fig. 1a, this being the reference point.

Phase change with pure tones.

Before considering a signal of complex shape it will be of interest to show the effect of carrier phase shift on a sine modulated wave with deep and shallow modulation and the curves for this case are shown in Figs. 1, 2 and 3.

Fig. 1 is reproduced from the previous article and shows that with deep modulation (100%) and a pure tone signal, considerable distortion occurs with very small

*The first five articles in this series appeared in the MARCONI REVIEW Nos. 9, 10, 11, 12, and 13.

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phase shifts of carrier. Figs. 2 and 3 depict the case where the percentage modulation is 50% and 25% respectively. The latter curves show two remarkable features. First as the depth of modulation decreases the distortion decreases, in fact with shallow modulation such as 25% the distortion almost entirely disappears except with phase shifts approaching quadrature.

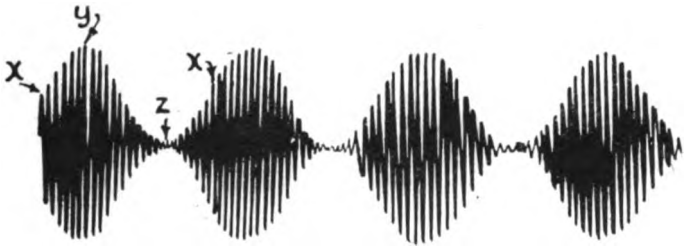

FIG. 1A. *Sine signal. Carrier correct frequency. Both side bands. Carrier correct phase.*

FIG. 1B. *Both side bands. Carrier 10° advance.*

FIG. 1C. *Both side bands. Carrier 45° advance.*

FIG. 1D. *Both side bands. Carrier 90° advance.*

The second remarkable feature is that the effect of shifting the phase of carrier is not to alter the position of the modulating signal on the time base but all that happens is a decrease in the effective depth of modulation; thus considering the case of a signal 25% modulated, as the carrier phase is shifted from 0 to 90°, the depth of modulation progressively decreases, slowly at first, but rapidly as the phase shift approximates to quadrature until with a phase shift of exactly 90° the modulation has almost completely disappeared.

If the shift of phase is increased beyond 90° the modulation re-appears with a reversed sense and with a phase shift of 180° of carrier, the signal resumes its original depth of modulation but with a reversed sense. It can be imagined that for a signal envelope to go through a process of being turned inside out as it were, necessitates a

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transition stage where the effective modulation is decreased as shown. With the pure tone signal this reduction of effective modulation is accompanied by distortion as observed. It is important to observe that this decrease of the effective modulation is not the only effect present, for a careful examination of the resulting wave form will show that the wave radiated is now not quite constant infrequency but varies between limits which increase as the apparent depth of modulation decreases. This will be referred to later.

Phase change with complex tone.

If the signal is not a pure tone but a complex signal the distortion is less marked as would be expected and this is shown in Fig. 4 where an example is given of a signal having a third harmonic. Fig. 4, a, b, c and d show the case of a carrier wave 50% modulated by a signal having a strong third harmonic, the phase shift of carrier being indicated on the diagram. These figures show how little distortion appears as the carrier phase is changed, and it is seen there is no relative phase shift of harmonic to signal fundamental as there is in single side hand working, that is to say, the effect of a shift of carrier phase for shallow modulation in ordinary telephony is not to produce serious distortion, but merely to alter the effective depth of modulation, the more complex the signal the less distortion there is apparent ; that is assuming such a wave be received by a system which responds to amplitude changes only. For at present almost all systems operate on amplitude change and any small frequency variation would pass unobserved.

Vector Analysis.

It is of interest to analyse exactly how it is these results can come about and we can best discuss the sine signal case. A sine modulated carrier may be thought of as being built up of a carrier wave, on either side of which is a single side band wave, each side band having the same difference of frequency above and below the carrier. Thus we have to think of the addition of three rotating vectors, a carrier vector and two side band vectors, one gaining and one losing an equal amount on the carrier vector as shown in Fig. 5 ; for the case of 25% modulation the amplitude of the carrier vector will be eight times each side band vector. Now since at all moments one side band is gaining on the carrier as much as the other side band is losing, we can for convenience consider the carrier vector stationary and the side band vectors rotating, the faster one in an anti-clockwise direction and the slower one in a clockwise direction at the same rate that of the modulation ; thus the vector *resulting from the side* band vectors will always be exactly in phase or in phase opposition to the carrier vector but it will vary in amplitude from zero (that is when each side band is in quadrature with the carrier but in phase opposition to the other) to a vector which will be 25% of the amplitude of the carrier and in phase ; to a vector 25% the amplitude of a carrier but in phase opposition, this cyclic variation of the resultant side band vector producing the modulation envelope. Such a method of looking at a modulated carrier provides a simple analysis, for the addition of any group of upper side band

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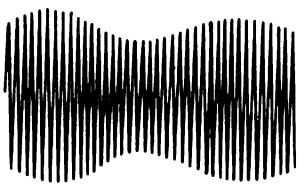
vectors to its corresponding group of lower side band vectors must always produce resultants which are exactly additive to, or must be subtracted from the carrier directly. This vector group will be rotating at a constant speed of the carrier frequency and since the resulting side band vector is always in phase or in phase opposition to the original carrier, it is clear that the resulting wave is one of constant frequency but changes in amplitude.

50% *modn.* *Carrier* 0°.

50% *modn.* *Carrier* 30°.

50% *modn.* *Carrier* 90°.

FIG. 2.



25% *modn.* *Carrier* 0°.

25% *modn.* *Carrier* 70°.

25% *modn.* *Carrier* 90°.

FIG. 3.

If we now consider a carrier having a phase shift of say 90° it means that the sum of the side band vectors must not be added directly to the carrier, but in quadrature, as shown in Fig. 5 ; because of this if the carrier vector is large compared to the side band vector (as it will be for shallow modulation) the resultant amplitude of these two vectors added in quadrature will always be approximately the same, for a small vector added in quadrature to a large vector gives a resultant vector of almost the same amplitude as the larger vector, as shown in Fig. 6.

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Considering the rotation of this group of vectors, our carrier vector is the reference point and it is clear that the vector resulting from the carrier and the side bands no longer maintains a constant position relative to the carrier but it is at one time leading it and another time lagging it ; in fact there is a cyclic variation at the modulation rate and we therefore come to the conclusion that the resulting wave is no longer constant in frequency but varies cyclicly with the modulation frequency, this frequency variation being additional to the small cyclic change of amplitude.

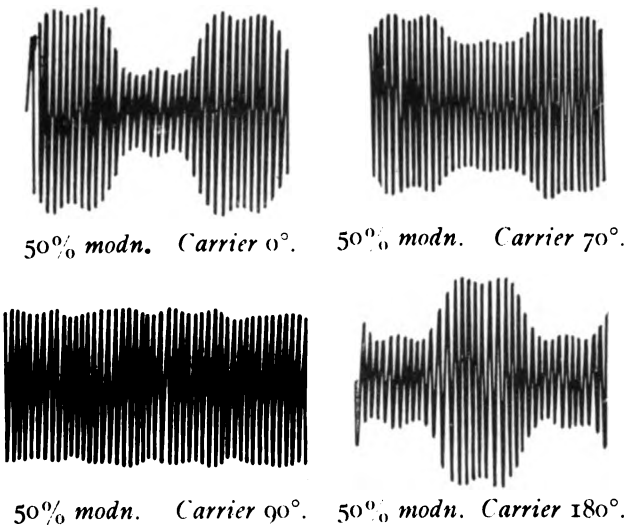

FIG. 4.

From this vector consideration it is also clear why with a phase shift of carrier the decrease of modulation is slow to commence with but changes more rapidly as the phase shift approximates to 90°. For the relationship of the resultant side band vector to the carrier is dependent upon a sine function of carrier phase shift.

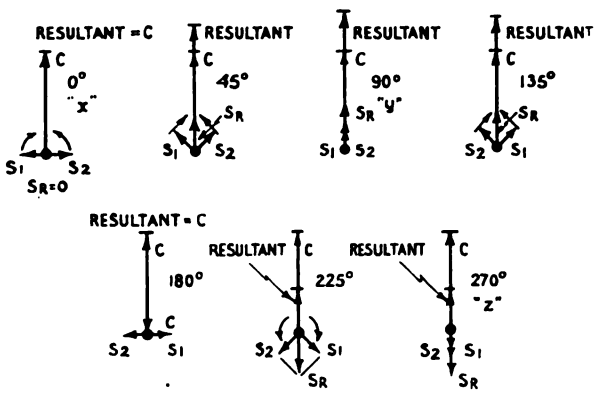

FIG. 5.

Summing up we reach the following conclusions, that the effect of phase shifting the carrier wave of an ordinary amplitude modulated carrier has the effect of reducing the amplitude modulation and introducing a frequency modulation, and that under conditions of shallow modulation the change of amplitude may become negligible with a carrier phase shifts approaching quadrature although a change of frequency will have been introduced which may become fairly considerable.

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With an ordinary receiving system designed to detect amplitude modulation, the signal will have disappeared, and if it is desired to obtain intelligence some form of demodulation which will respond to frequency changes in addition to amplitude changes becomes necessary.

Asynchronous Fading.

It is now of interest to discuss whether such phase shifts of carrier can occur in practice and there is considerable evidence that such a phenomenon can and does exist. Hitherto we have always considered that æther waves are propagated with the velocity of light and hence we have assumed that a complex modulated wave radiated from a transmitter, which may be considered as consisting of a spectrum of waves, is propagated through the æther at the velocity of light and that the phase relationship of each wave of the group will be unchanged when it arrives at the receiver.

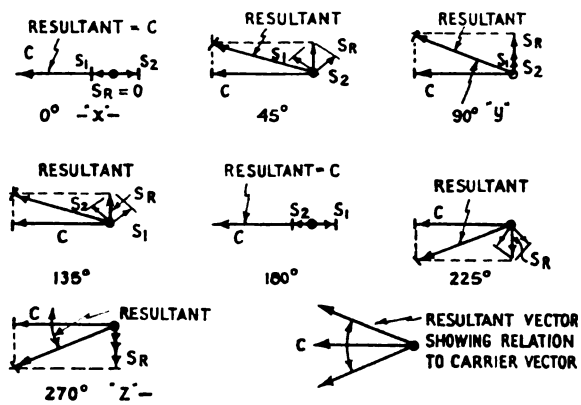

FIG. 6.

Continued observations of short wave signals, however, have suggested that this idea may not be correct; for instance there is a well-known type of fading which may be observed on long distance short wave telephony where but small distortion appears with fading and the fading of the carrier wave does not synchronise with the fading of the modulation; in fact there have been occasions when the modulation has weakened or faded out but the carrier, far from fading, has appeared actually to strengthen. This effect was observed by Mr. Langridge, and the writer in 1926 and at the same time no marked distortion was noted.

Generally speaking, fading is considered to be a phenomenon due to the reception of multiple rays interfering with one another. If one considers fading of the type described above it is very difficult to understand how addition of multiple spectra can produce a fading of side bands without carrier and further the addition of multiple spectra will usually involve distortion. It is suggested that a simple phase shift of carrier relative to side bands as the spectrum passes through the medium is sufficient to explain this particular type of fading. Although the idea that electromagnetic

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waves of different frequencies have different velocities of propagation is not one usually considered, when it is remembered that short waves are not propagated solely through a pure æther medium but through an ionised layer, then a variable wave velocity is a probabilty ; in fact the idea is allied to some extent to the low frequency case of the propagation of low frequency waves along a transmission line where the different frequencies suffer different attenuation and different phase shifts.

If such a phenomenon is existent, what we require to overcome this type of fading is a receiving system which has two separate functions, first to respond to change of amplitude and secondly to change of frequency, the signals being added after demodulation. Theoretically this would be a solution but with present-day apparatus it is very doubtful whether any such receiver would operate owing to the difficulty of obtaining sufficient frequency constancy. For the effect we are discussing is resultant upon a small phase change of carrier frequency of an amount commensurate with the modulation and although our carrier waves are reasonably constant, they are not sufficiently so to think of phasing them. When one is dealing with frequencies of the order of 10,000,000 cycles one requires a constancy of one part in 50,000,000 at least before we can hope successfully to operate a system which depends for its action upon the relative phases of the waves comprising the signal. A. W. LADNER.

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MARCONI NEWS AND NOTES

BROADCAST TO UNITED STATES FROM THE "ELETTRA."

Marchese and Marchesa Marconi with Signor Mussolini on board the S.Y. "Elettra."

MARCHESE MARCONI'S new short-wave telephone apparatus on board his yacht *Elettra* was used for an unusual broadcast on July 28th, when newspapermen delivered eye-witness accounts of Italian earthquake disaster for American listeners.

The transmissions from the *Elettra*, which was lying off Civita Vecchia, were picked up by the receiving station of the National Broadcasting Company of America near New York and successfully rebroadcast throughout the United States.

The speakers were representatives of the International News Service, who hurried straight from the scene of the earthquake to the *Elettra* to deliver their accounts of the scenes in the stricken areas.

This is the second occasion on which Marchese Marconi's new telephone has been heard by American listeners. On April 30th Marchese Marconi on board the *Elettra* in the Mediterranean was "interviewed" by Mr. Karl Bickel, President of the United Press of America, who was in New York 4,400 miles away, and the interview was rebroadcast throughout the United States.

Marchese Marconi Speaks to Melbourne Radio Exhibition.

The interest aroused throughout Australia by the experiments recently carried out by Marchese Marconi on his yacht while in Italian waters, and by his demonstration in switching on the lamps at the Sydney Radio Exhibition and speaking by wireless telephone to Sydney at the opening ceremony, led to a request that he should take part in the opening of the Melbourne Radio Exhibition on July 18th.

Acceding to this request, Marchese Marconi spoke to the Chairman of the Melbourne Exhibition by wireless telephone from his yacht *Elettra*, following the opening of the Exhibition by the Lord Mayor of London, who, by pressing a button at the Mansion House, London, lit a sign declaring the display open.

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THE MARCONI REVIEW

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THE MARCONI REVIEW

No. 24. *September, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

HARMONIC ATTENUATION

In the following article, the causes of the radiation of harmonic frequencies from a transmitter in addition to the required fundamental are described, and the result of such radiation, and means of practically eliminating all frequencies other than that desired, are discussed.

It is shown that filter circuits between the output of the transmitter and the aerial, and suitable precautions taken in the design of the transmitter itself, go far to avoid any disturbing radiation of harmonics.

ALTHOUGH the thermionic triode is without question the most effective instrument yet available for the purposes of generating and amplifying high frequency oscillations, nevertheless there are certain disadvantages noticeable in its practical applications which result in a marked departure from the ideal performance of a perfect device. Of these disadvantages, probably the most serious in effect, and the most difficult to counteract, is the tendency of the valve to produce not only the required fundamental frequency, but a series of partials or harmonics, varying in their amplitude ratio to the fundamental according to the particular adjustments of the valve and the character of its associated circuits, but always present in a more or less disturbing degree in every installation operated at reasonable efficiency.

The production of these undesired frequencies is normally due to a combination of causes. In the first place, the characteristic curves of the valve are not linear throughout their full extent. Secondly, in the interests of efficiency, amongst other reasons, it is essential to adjust the operating point of the valve in such a manner that at most only one half of the grid swing is effective in varying the anode current. Other causes which may act detrimentally to the production or reproduction of a pure wave form are the variation in amplitude of the grid current during a cycle, and the damping effect of the load on the oscillatory current in the output circuit of the valve.

The net result of these various phenomena is that even if a sine voltage is applied to the grid the oscillation produced in the output circuit is distorted, and this distorted wave form is resolvable into a fundamental frequency and a series of harmonics.

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If these harmonics are permitted to be radiated from a transmitter, it is clear that the particular station is not only occupying its allocated position in the wave band, but is to all intents and purposes a multi-wave transmitter with possibilities of disastrous interference with numerous other lines of communication.

The greater the power of the transmitter, other things being equal, the greater will be the power and interfering range of the harmonics, and, consequently, the greater the necessity for precautions against such radiation.

The problem is of the first importance in connection with every transmitter of any power working above about twenty metres, and until an adequate solution is found, and, in addition, universally applied, carefully considered allocations of wave lengths to particular stations and classes of service, and elaborate arrangements for ensuring stabilisation of frequency will to a considerable extent be nullified and the full benefits of such organisation fail to be realised.

As matters are at present lower harmonics of the long wave telegraph stations disturb broadcast listeners, second harmonics of broadcasters in the upper part of the band interfere with those lower in the wave scale, and all of these may badly jam short wave services of many kinds. In the short wave band itself, the radiation of harmonics can produce unexpected and far reaching effects, due to the fact that under certain conditions of time and season particular frequencies are transmitted with extremely small loss, so that even a very low power under these conditions will produce an operative signal at remarkable distances.

Cases are frequently recorded of a short wave transmitter several thousands of miles distant from the receiving point being clearly received on a harmonic at times when its fundamental has been completely inaudible. Such effects, although occasionally convenient, are obviously quite inappropriate to a well ordered scheme of frequency allocation.

Clearly, improvement on normal existing practice is called for, and the object of the present article is to call attention to certain possible remedial measures which are applicable, although, unfortunately, not all without additional expense and some degree of complication.

It is apparently impossible with any feasible arrangement of existing valve oscillators to prevent the generation of harmonics, and efforts therefore have to be confined to the prevention of their direct radiation, and to means for securing maximum attenuation before they reach the aerial.

Some idea of the numerical values to be expected in practice will assist in forming an appreciation of the problem involved.

As previously indicated, the strength of the radiated harmonics in comparison

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with the fundamental, varies widely as between different types of transmitter. In the case of a telegraph transmitter of a very usual sort, the ratio of the field strength of the strongest harmonic, generally the second or double frequency wave, to the fundamental measured a few miles from the station, may be as high as $\frac{1}{100}$, while with a modern broadcast transmitter, this fraction may be as low as $\frac{1}{2000}$.

These figures, of course, correspond normally to very small amounts of energy. In the worst case mentioned the harmonic energy radiated is only $\frac{1}{10^4}$ of the fundamental, and in the latter example only $\frac{1}{4 \times 10^6}$.

Unfortunately, even such comparatively small powers are capable of causing considerable trouble in a sensitive receiver. A concrete example, based on field strength measurements taken at a distance of five miles from a certain broadcasting station of the most modern type, may be of interest. The particular transmitter operates with about thirty kilowatts carrier energy in the aerial, and incorporates a number of precautionary measures tending towards attenuation of the harmonics. In this case the field strength of the fundamental at the distance mentioned was found to be approximately 300 millivolts per metre, while the second harmonic was about 150 microvolts, say a ratio of $\frac{1}{2000}$, or an energy of $\frac{1}{4 \times 10^6}$ of the fundamental. In the particular example, this would mean that the power of the strongest harmonic is of the order of one hundredth of a watt, which might appear to be a negligible quantity.

The field strength of 150 microvolts produced at five miles would, however, be far from negligible if attempts were being made to receive a distant transmission of the same wavelength as the harmonic, but to appreciably reduce the already minute harmonic energy radiated is obviously a problem of some magnitude.

There are certain possible features in the design of a valve transmitter, incorporation of which will prevent the harmonic radiation reaching a strength it might otherwise attain, and amongst these precautions the following are worth noting.

The oscillatory circuit of the valve should either be so proportioned that the correct alternating anode volts are secured with the anode tap connected directly to the tuning condenser, as in Fig. 1, or if such a ratio of inductance and capacity is not feasible, then the tuning condenser should preferably be arranged with units in series, and the anode tapped down the condenser, as in Fig. 2, rather than be tapped down the inductance, as Fig. 3.

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In the coupling of valve circuits in cascade, or in the coupling of a valve circuit to an aerial, there is a useful advantage obtainable by utilising a condenser as the coupling member in place of an inductance. This advantage becomes very marked as regards the higher harmonics, seeing that the harmonic voltage produced across a condenser, as compared with the voltage drop across an inductance of equal impedance to the fundamental, is in the ratio of $\frac{1}{n^2}$, where n represents the number of the harmonic.

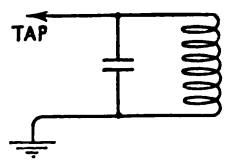

FIG. 1.

It is desirable again to connect the coupling member in the inductive branch of an oscillatory circuit rather than in the capacity branch, for example, an inductive coupling should be arranged as in Fig. 4, and not as in Fig. 5, and a capacity coupling as in Fig. 6, in preference to Fig. 7.

From the point of view under discussion, the negative grid bias applied to the valve should be a minimum, as a heavy grid bias results in short flicks of anode current producing a wave form in which harmonics are very pronounced. In this respect the most favourable type of transmitter in normal use is that used widely for broadcasting purposes, wherein the high power stages amplify modulated oscillations, and in which in the interests of linear reproduction, it is essential that the complete positive half cycle of the grid input voltage is effective in varying the anode current, notwithstanding the reduction in efficiency which such a method involves. This is an important advantage possessed by the low power modulation system over the alternative full power modulation method, in which, in order to secure a reasonable overall efficiency, it is imperative to operate the high frequency amplifier on the "flick" method with the consequent high harmonic production. Theoretically, some alleviation of the harmonic trouble is obtainable by arranging the valves in the so-called "push-pull" connection, which should result in a balancing out of the even harmonics, but exactly how effective this is in practice, particularly on high power sets where a number of valves are concerned, is somewhat doubtful. A point in design which may reduce direct radiation in some degree, is to construct the tuning inductance of the oscillatory circuit in the form of an astatic pair.

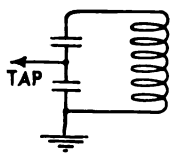

FIG. 2.

A factor in the adjustment of a transmitter which can exercise a marked effect on the distortion of the wave form is the degree of coupling between the output circuit and the load.

If the damping imposed by the load is too great, or if in other words the ratio of the output circuit volt amperes to the load circuit watts is too small, there will,

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with the normal single circuit, be a marked difference in amplitude between the half cycle during which energy is being fed to the circuit and the half cycle when energy is only being abstracted from the circuit. This difficulty can be overcome by adopting the " push-pull " arrangement, and so allowing the valves to provide energy each half cycle.

Another favourable feature in the design of a station is the locating of the aerial and its tuning components at a distance from the transmitter, and the provision of a feeder or transmission line for linking purposes. By this means the aerial is less likely to be influenced directly by harmonics existing in the valve circuits, and with suitable coupling devices a useful reduction of harmonic radiation is possible. The adoption of such a feeder lends itself conveniently to the inclusion of harmonic " traps " tuned to the undesired frequencies, these " traps " taking the form either of rejector circuits placed in series in the feeder leads, or of acceptors connected from the feeder leads to earth. Where it is desired to attenuate some particular harmonic, particularly one of a high order, such " traps " have useful possibilities, but, so far as the writer's experience goes, where the second harmonic is concerned the improvement resulting is not normally sufficient to meet modern requirements.

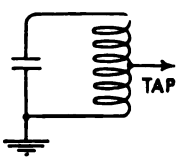

FIG. 3.

Similar tuned " traps " have, in some cases, given favourable results when inserted in various positions in the valve circuits themselves, but where such attempts are made, care should be taken to effectively screen the " trap," or the effects of direct induction on neighbouring circuits may make the trouble even worse than originally.

Even with all the palliatives enumerated above incorporated in a valve transmitter, it is unhappily a fact that in most cases the strength of the harmonic radiation will still be sufficient to cause troublesome interference on wavelengths where ideally such interference should be non-existent, and we are forced, therefore, to seek for further and more definite safeguards.

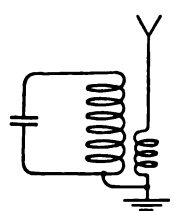

FIG. 4.

Probably the most effective means for obtaining the desired degree of immunity is the insertion of a suitably designed wave filter between the output circuit of the transmitter and the aerial. It would seem that credit for first utilising this useful device in connection with radio transmitters should be accorded to the Marconi Company, inasmuch as that Company initiated experiments on such lines at Chelmsford and Ongar as long ago as 1922, when it was shown that a low pass filter could produce a considerable harmonic attenuation without appreciably affecting the efficiency of the transmitter on its fundamental frequency. This development was probably some-

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what in advance of its time at the date mentioned, and no commercial use was made of it until more recently, when the problem of harmonic interference was brought into particular prominence, due to the advent of broadcasting, with its resultants of numerous transmitters, many of considerable power, and an enormous number of private receiving stations.

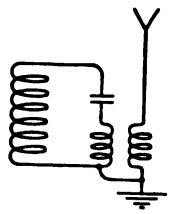

FIG. 5.

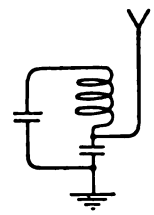

FIG. 6.

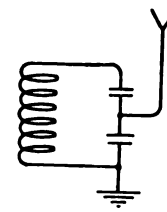

FIG. 7.

The filters normally used have been three stage low pass of T section, with the components mounted in screening cases constructed in sections shielding one stage from another.

Fig. 8 represents a diagram of such a filter with one possible arrangement of coupling to the valve output circuit and to the aerial.

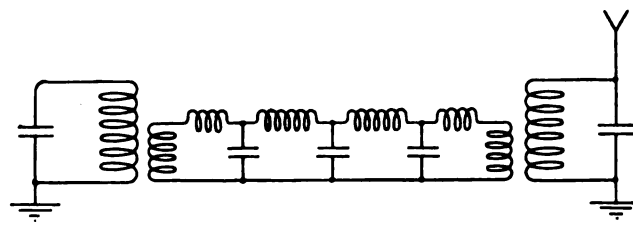

FIG. 8.

The filter, naturally, will only operate effectively in conjunction with a certain terminal impedance for which it is designed, and if a feeder line is to be included it is also essential that this should possess the same surge impedance. For medium wave transmitters using open feeders an impedance of about 600 ohms has been found convenient, and the apparatus is usually designed to meet such conditions.

A filter of the type mentioned above will theoretically produce an amplitude attenuation in the cut off region of some 48 T.U., so if properly used such a filter may be expected to attenuate the harmonics to at least $\frac{1}{100}$ of their original amplitude, and this degree of attenuation should be sufficient, provided the transmitter has been

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intelligently situated in regard to centres of population, to give a satisfactory immunity from disturbances in the majority of cases. Of course if essential, as far as the filter itself is concerned, this can be made still more selective by increasing the number of stages.

A factor not always realised, but nevertheless of primary importance in relation to the practical effectiveness of any form of harmonic attenuator is the degree of screening provided against direct radiation from the valve circuits, more particularly of course in the high power stages of a cascaded transmitter.

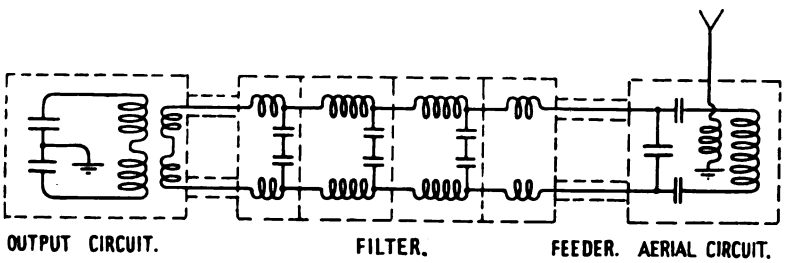

FIG. 9.

It has frequently been observed, when making measurements of harmonic field strength at short ranges from a transmitter that the disconnection of the aerial from the set, other circuits being maintained under equal conditions, has produced no appreciable reduction of harmonic strength. Quite obviously in such cases the insertion of a harmonic attenuator between the output circuit and the aerial is perfectly useless.

Not only should the transmitter circuits and the attenuator be effectively shielded but also the leads connecting the transmitter to the attenuator, otherwise harmonic fields will, as it is termed, " jump " the attenuator, and induce voltages on the wires leading out from the attenuator and thence influence the aerial.

The ideal arrangement, therefore, would be as outlined in Fig. 9 in which the dotted lines represent the earthed metal shielding cases.

The diagram represents an arrangement suitable for working with a " push-pull " output circuit, a very desirable method when a feeder line is included in the set, as it is then easy to arrange for each of the feeder wires being at the same potential above earth, which tends to facilitate securing correct adjustments.

Unfortunately it is a very difficult matter effectively to screen a large transmitter in a practical manner. Various supply leads and water pipes have to be led into the valve enclosures and numerous indicating instruments must be arranged visibly, all of which make it almost essential to provide several apertures in the screening cases.

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Probably an effective scheme would be, in addition to individual screening of the different valve stages, to instal the transmitter in a metal building, or in a brick building lined with metal, with the screened harmonic attenuator placed either externally or in a separate compartment inside the building, the input leads as previously recommended being run in shielding trunks.

Another possibility would be to place the transmitter below the ground level, and to cover the crypt or basement with a metal roof, which might form the floor of an upper storey housing control rooms, machinery, hall and offices. Such an arrangement could most probably be made remarkably effective, and may well be an approved design for radio stations of the future.

Naturally none of these constructions can be incorporated without materially increasing the initial cost of the complete station, and for this reason, presumably, little has been done on such lines up to the present.

It is the writer's opinion, however, that before long innovations on the lines indicated will have to be introduced by those bodies responsible for the operation of radio services, and it is not unlikely that international regulations will force the issue and make it imperative for all concerned to utilise to the utmost every device known for minimising the existing harmonic nuisance.

W. T. DITCHAM.

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TONE MODULATION OF TELEGRAPHIC TRANSMITTERS

PART II.

The following article completes the discussion on the Tone Modulation of Telegraph Transmitters, which appeared in the July Issue of THE MARCONI REVIEW.

It is thought that the practical nature of the various points dealt with will be appreciated by those who are particularly interested in Marconi Transmitting Apparatus.

Tone Modulation applied to the Absorber Method of Keying Transmitters.

THE object of including an absorber in the general scheme of transmitter equipment is to ensure steady load conditions as between "mark" and "space," it is, in fact, the only satisfactory method of keying when speeds of over 100 w.p.m. are desired and is a feature of the high power Marconi-Franklin Beam Transmitter.

In order to obtain Tone Modulation of the standard transmitter there are two methods available, viz., supplying the set from a source of unsmoothed rectified A.C. and, secondly, keying the set at a sinusoidal tone-frequency, a method that is suitable when the supply is in the form of direct current. Dealing with the latter method first, Fig. 5 represents the scheme of keying a S.W. transmitter : it will be understood that with "key open" there is sufficient negative bias on the grid of the sub-absorber valve to render the latter non-conductive : this condition implies a comparatively high potential at the sub-absorber anode, which is applied, at a suitably reduced value via the floating battery, to the grid of the main absorber, and renders it conductive. Again, owing to the drop across the main absorber resistance, this implies low potential at the main absorber anode and consequently insufficient energy to cause No. 2 amplifier to operate and drive No. 1 Power Amplifier. Conversely, with the key closed, the alternating potential already existing across R_L is now applied to the grid of the sub-absorber valve, rendering the latter alternatively conductive and non-conductive ; that is, its anode will experience an alternating change of potential. It follows that the final or Main Power Amplifier will be alternatively driven and not-driven, thus the output during "mark" will be a series of more or less sinusoidal periods of radiation, and in Fig. 6 an attempt is made to illustrate the theoretical variation of anode current for various degrees of sub-absorber grid bias and various degrees of swing (power) of the tone modulator. In the figure, (A) illustrates the effect on the Sub-Absorber Anode Feed, of varying the amplitude of A.C. potential applied to the grid, after the grid bias has been so adjusted that under static conditions the anode current is just cut off. Again (B) illustrates the effect, on Anode Feed, of varying the bias applied to the sub-absorber grid when the amplitude of grid A.C. potential remains constant. In practice the effect is decidedly differential, since the positive A.C. amplitude automatically

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increases as the damping is reduced, that is, as the negative bias is increased. It will be observed that the dotted line indicates grid potential while the full line indicates anode current : note that the final output of radio waves from the antenna follows approximately the variations of the sub-absorber anode current and thus, in a way, the full line curve represents the theoretical variation in the final transmitter output.

Owing, however, to transient inductive effects the theoretical output is not realised in practice, and the actual output of the Main Power Amplifier is more than normally reduced when tone frequency variations are applied to the grid of the sub-absorber valve. In Fig. 7 the " trace " (a) is an actual oscillagraph of the

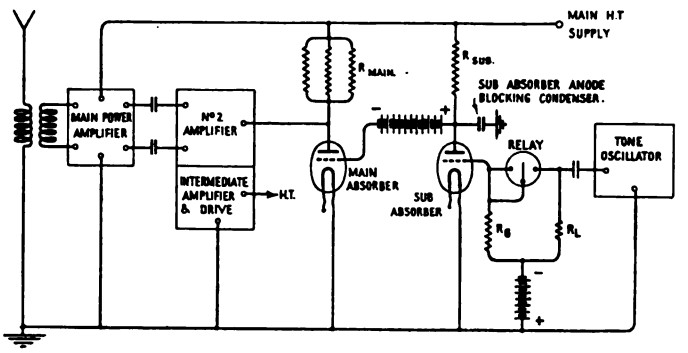

FIG. 5.

rectified output of a transmitter sending at the rate of 150 w.p.m. with a tone modulation of 500 cycles : taking the basis of emission for pure C.W. to be 100 per cent. it will be seen that the signals for tone modulation are only active for some 25 per cent. of the period. Now the writer has found that this effect may be controlled by the expedient of inserting a blocking or curbing condenser between earth and sub-absorber anode, below the anode resistance—see Fig. 5—and in Fig. 7 the traces (b), (c) and (d) illustrate the effect of 0·05 and 0.10 mfds. inserted in combination with three values of resistance. Clearly to obtain a given effect the capacity has to be chosen with reference to the value of resistance (see note) and to the tone frequency.

In passing, it may be mentioned that results obtained at the receiving stations have indicated that the curbing condenser " cleans up " the signals, that is, it tends to eliminate the higher harmonics and leads to very satisfactory reception.

Full Wave Rectification of Tone Oscillator.

Another method of overcoming the diminution of radio frequency power is to pass the tone oscillator output through a double electrode rectifier, before applying

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it to the grid of the sub-absorber ; this method, however, possesses the following three minor disadvantages :—

(A) It is still preferable to apply a small amount of curbing, in order to filter out the higher harmonics.

(B) It involves another valve, with A.C. filament supply and transformers.

(C) The doubling of the tone frequency, as has been explained, is a retrograde step—of course the tone oscillator frequency can be halved, but this implies a very low frequency indeed.

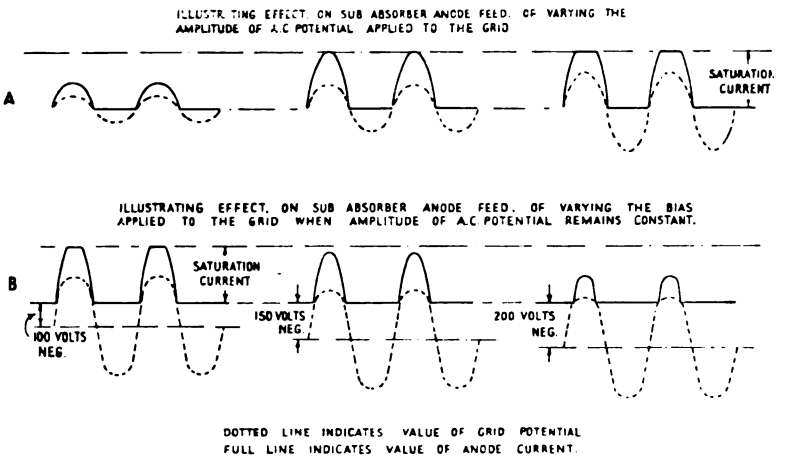
ILLUSTRATING EFFECT ON SUB ABSORBER ANODE FEED OF VARYING THE AMPLITUDE OF A.C POTENTIAL APPLIED TO THE GRID
A
SATURATION CURRENT
ILLUSTRATING EFFECT ON SUB ABSORBER ANODE FEED OF VARYING THE BIAS APPLIED TO THE GRID WHEN AMPLITUDE OF A.C POTENTIAL REMAINS CONSTANT.
B
SATURATION CURRENT
100 VOLTS NEG.
150 VOLTS NEG.
200 VOLTS NEG.
DOTTED LINE INDICATES VALUE OF GRID POTENTIAL
FULL LINE INDICATES VALUE OF ANODE CURRENT.

FIG. 6.

Note on Absorber Keying.

It not infrequently happens that, after some months running, complaints are received of " spacing waves " being sent out by the transmitter, despite the fact that all the oscillatory circuits have been carefully balanced and that the usual routine inspections and check adjustments have been properly carried out. The trouble, however, may be that of the main absorber valves gradually losing their pristine emission, and since the falling off in anode current has been slow, and in any case slight, *e.g.*, falling from 1·60 amps to 1·50 or 1·55 amps, the factor remains overlooked and yet may be sufficient to reduce the drop in potential across the main absorber resistance to an extent that increases appreciably the potential applied to No. 2 Amplifier Anodes. The effect of this is to drive No. 1 Main Amplifier, feebly perhaps, but still sufficiently to energise the circuit and cause the emission of low power waves, which, despite the absence of any indication on the feed ammeters, under good conditions reach the receiving station with sufficient strength to interfere with signal formation.

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It will be found that adjusting the floating main absorber grid bias battery has very little effect on this condition at the Absorber Panel, and though increasing the brilliancy of the valve filaments may improve matters, the improvement is only temporary, and a costly one in respect of valve life. The better way is to increase the main grid current by reducing the value of the series resistance R_{SUB}, see Fig. 5, between main H.T.V. supply and main absorber grid, in other words by reducing the value of the sub-absorber anode resistance, since this is one and the same thing.

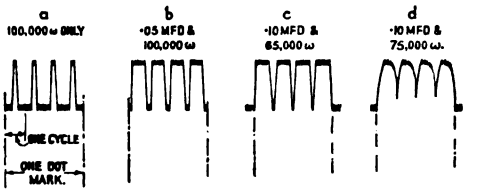

FIG. 7.

It is in fact better to make the initial adjustments of the set such that the main absorber grid current is fairly high, for if so, it will be found that the valve emission will remain steady at the required value over a long period. Of course the sub-absorber anode feed will be increased in proportion but it should still be well within the safe limits of emission for the type of valve employed. For standard transmitters the value of R_{SUB} may safely be of the order of 55,000 ohms.

An interesting overall check on this adjustment is to note the No. 2 Magnifier anode current reading during the " space " period before and after an alteration in the main absorber grid current.

High Power Tone Modulation.

When the main supply to the transmitter is single phase A.C., the smoothing system in the main rectifier may be cut out, a process which restores the feed to simple full wave rectified A.C., that is, to a series of direct current impulses of twice the frequency of the supply and of approximate sine formation—the voltage rising to peak values that may vary from 1·2 to 1·5 times the voltage of the original smoothed current. With this form of supply the output of the transmitter obviously becomes effectively tone modulated, and in fact the method is the most satisfactory form of tone modulation, when a single phase supply is available. Mostly, however, the supply is 3 phase and for practical reasons one aims at designing the plant with the minimum amount of running machinery possible, a principle which precludes transforming from three phase to single phase simply for the sake of tone modulation. On the other hand where the station is self-contained with its own source of power, there is no reason why the individual transmitter supply units should not be single phase, and the following few notes may be of service.

In Fig. 8 the item (A) indicates a theoretical current or voltage curve for unsmoothed rectified A.C.; owing, however, to transformer induction the current is distorted from pure sine formation and does not fall to zero value, the result

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being as indicated by item (B). Now this distortion introduces harmonics while the imperfect cut-off probably reduces modulation to a figure of about 80 per cent. If, however, the supply is shunted by a small value of capacity—*i.e.*, if a little of the original smoothing bank of condensers, say 0·2 mfds. in the case of the 20 kw. Standard Beam Transmitter, is left in—then the trough of the current or voltage supply is rounded off, as depicted at (C), and the higher harmonics are thereby

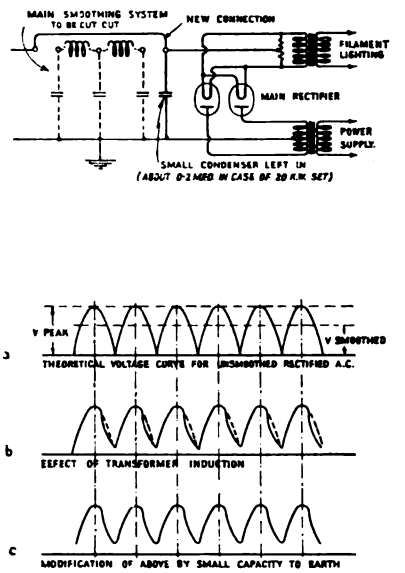

FIG. 8.

eliminated. It is true that the percentage modulation is further decreased, perhaps to 70 per cent., but, as already pointed out, this is a very desirable and important compromise when high speed working is aimed at ; in any case the gain at the receiver due to the narrowing of the wave band appears to be well within the paying limits of this compromise. Thus during a series of tests over some thousand of miles the difference between plain unsmoothed supply and unsmoothed supply modified by a shunt of 0·2 mfds. capacity gave average readings on the receiver heterodyne vernier condenser of 25 degrees and 15 degrees respectively, representing in this instance, perhaps, total widths of bands of 10,000 cycles and of 7,000 cycles. In the first case the series of reports, summarised, were as follows : " Signals strong but formation poor on slip at 200 w.p.m. Slip O.K. at 175 w.p.m.," while in the second case the reports might be summarised as : " Signals strong and steady. Good slip at 200 w.p.m."

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Tone Frequency.

The single phase alternators should not be run above such a speed as gives 250 cycles, equivalent to 500 cycles when double rectified. In the case of sets designed to supply single phase A.C. to new stations, that is, where there is freedom of choice of machine periodicity, the latter should be specified not higher than 200 cycles, to give a note of 400 cycles.

Valve Saturation.

A fault to guard against when employing high power tone modulation is that the peak anode voltages may cause a momentary saturation of the main magnifier filaments, and to a lesser extent of the other magnifier filaments ; this may not be discernible on the instruments but will lead to " flat top " emission and consequent accentuation of the higher harmonics. For this reason it is preferable to run the valves at slightly higher voltages than are apparently necessary to avoid saturation.

Moving Coil Instruments.

It should be realised that moving coil meters are not reading correctly when the main supply is unsmoothed A.C. and that effective voltages and currents will be about 1·2 times apparent readings.

N. WELLS.

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NOTES ON TRANSMISSION MEASUREMENTS

A brief survey of the development of the units used in transmission measurements up to the present day is given, together with formulæ and a table relating the various quantities.

The Marconi Transmission Measuring Set and its method of use are described and the questions of transmission levels and turnover are briefly discussed.

General Survey.

THE last few years have witnessed a great development in the methods of measurement and in the systems of units for use in determining the electrical transmission conditions existing in the medium of propagation and in the apparatus used for the transfer of intelligence from one place to another by electrical means.

Until about two years ago there were several systems of measurement in use, some of which were progressive improvements upon the earlier ones, which, however, had not been abandoned. In 1926 there was held in Paris the annual conference of the Comité Consultatif Internationale des Communications Téléphonique à Grande Distance, at which two new units, the Bel and the Néper were recommended as the basis of all future communications measurements.

It is interesting to note that these Units were named after Alexander Graham Bell the inventor of the telephone and Lord Napier the inventor of Logarithms.

The chief systems in use before the Conference were as follows :—

Mile of Standard Cable.
βl Unit.
British Standard Mile and
Transmission Unit.

The Transmission Unit and the βl Unit have been standardised as the Bel and the Néper, except that the Transmission Unit was raised to ten times its previous value, the original Transmission Unit becoming the Decibel or one-tenth of a Bel.

The popular abbreviation for Decibel is "db," although to the best of the Author's knowledge no official abbreviation was recorded at the Conference.

Explanation of Transmission Measuring Systems.

It should be clearly understood that all the units used for the measurement of transmission characteristics are relative. They differ greatly from the normal types of absolute measurement having a fundamental basis such as the centimetre, the gramme and the second.

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The use of a ratio does not require any knowledge of absolute values, for instance, we may know that a weight A is four times as heavy as a weight B without knowing anything about the actual values of the weights. If an absolute measure of the power in a circuit is required it is now general to measure what is known as the " level " of the circuit at any given point. The question of " level " and its measurement is discussed further on.

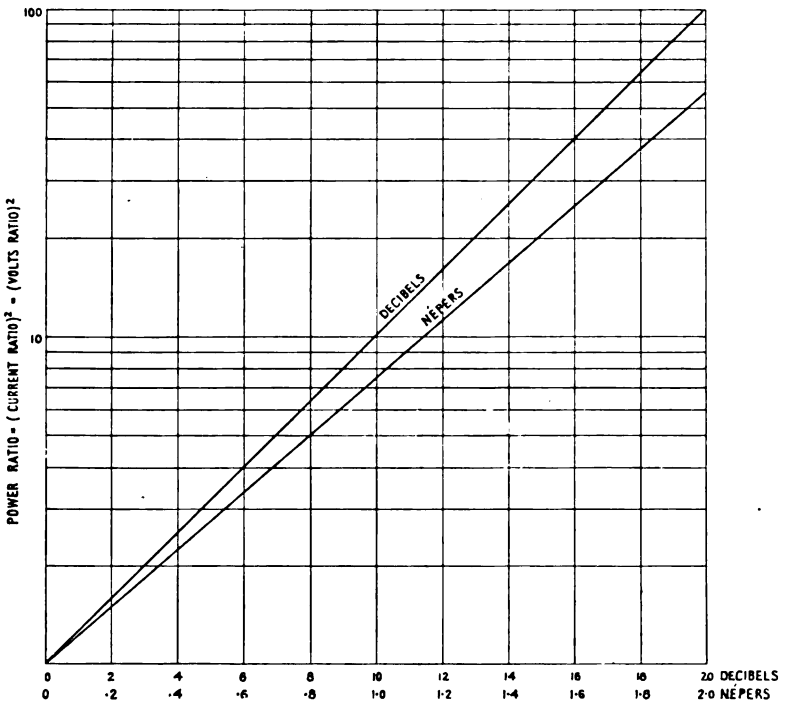

FIG. 1.

Some of the earlier attempts to measure transmission characteristics were carried out by comparing the cable to be measured with an arbitrary standard. This standard, known as the " Mile of Standard Cable," or M.S.C., was defined as being a cable having uniformly distributed resistance of 88 ohms per loop (go and return) mile, uniformly distributed capacity of 0·054 microfarads per mile and uniformly distributed inductance of 0·001 henrys per mile, while the shunt leakance was considered to be zero. American practice assumed the inductance to be zero as well as the leakance so that the English standard is approximately 3 per cent. higher than the American, that is to say that a cable measured in accordance with the American standard would appear to have an attenuation 3 per cent. higher than

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if it were measured with the English standard. By comparing the output from the cable under test with that from a variable artificial line having the above characteristics, with equal input currents, the attenuation or transmission characteristic of the cable may be ascertained. The results are, of course, stated in the form of a ratio, viz., that of the electrical length of the cable tested, compared with that of the standard.

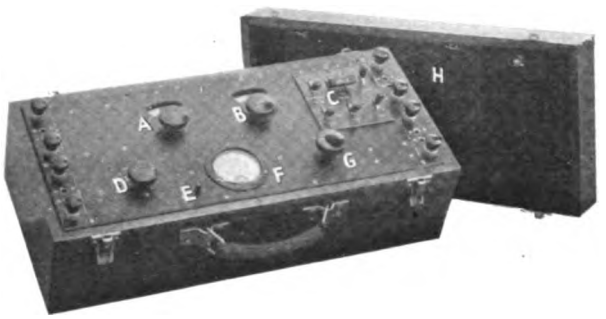

FIG. 2.

The formulæ connecting M.S.C. with current, voltage and power, are as given below:—

$$\text{M.S.C.} = 21{\cdot}12 \log_{10} \frac{I_1}{I_2}$$

$$21{\cdot}12 \log_{10} \frac{V_1}{V_2}$$

$$10{\cdot}56 \log_{10} \frac{P_1}{P_2}$$

where I_1 and I_2 = input and output current respectively.
V_1 and V_2 = input and output voltage respectively.
P_1 and P_2 = input and output power respectively.

It is, of course, essential that the currents be measured with the cable correctly terminated, unless allowance be made for any errors introduced by incorrect termination, since, although we may measure either the input and output currents or voltages, it is necessary to remember that we are actually interested in the transmission of power. A negative result in an attenuation formula should be taken to represent a gain instead of a loss.

All transmission measuring units are logarithmic in character as in the case of M.S.C., because the rate of decay of an impulse transmitted along a conductor follows a logarithmic or exponential law. For this reason, attenuation, which is a measure of the rate of decay, has also been measured in terms of natural logarithms;

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thus the ratio of the input to the output current may be used to ascertain the attenuation by the following formula :—

$$\text{Attenuation} = \log_\epsilon \frac{I_1}{I_2}$$

The attenuation as given by all transmission formulæ is, in general, a complex quantity of the form $\beta + j\alpha$, since there is usually a progressive change of phase as the impulse proceeds along the cable.

In addition we may measure attenuation in terms of the voltage or power at the end of the cable as a ratio of that at the input, in which cases the formulæ are as follows :—

$$\text{Attenuation} = \log_\epsilon \frac{V_1}{V_2}$$

$$= \tfrac{1}{2} \log_\epsilon \frac{P_1}{P_2}$$

The unit in which the above values of attenuation are expressed is the βl unit where "β" represents the attenuation per unit length and "l" is the length of the line. This unit which is sometimes known as a " Hyp " has not been much used on account of its size, which is rather inconvenient, whereas the M.S.C. which is approximately one-tenth of the size of the βl Unit has had an extensive application, both in this country and in America.

Referring again to the M.S.C. unit, it will be appreciated that as direct comparison is made with a standard cable or with a sub-standard artificial line equal to the standard cable, which is reactive, the attenuation of the standard will vary with the frequency, and therefore an arbitrary testing frequency of 5,000 radians per second (796·4 cycles per second) has been generally adopted. The fact that this frequency is now not generally considered to be a representative point in the spectrum of voice frequencies, and that the attenuation of the standard depends upon the frequency, has brought about the use of other units of measurement.

The British Standard Mile, or B.S.M., is another unit which, however, was not destined to receive widespread recognition as it showed no great advance upon those already existing. The relationship between the B.S.M. and other units is shown in Table I.

A great advance was made with the introduction of the Transmission Unit, which, under another name, is in almost universal use to-day. The Transmission Unit has several advantages ; it is not dependent on frequency, it is of a very convenient size, it is based on common logarithms instead of on Naperian logarithms and the factor appearing in the formulæ is an integer which is easily remembered.

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$$\text{T.U.} = 20 \log_{10} \frac{I_1}{I_2}$$
$$= 20 \log_{10} \frac{V_1}{V_2}$$
$$= 10 \log_{10} \frac{P_1}{P_2}$$

At the Conference of the C.C.I. in Paris, as mentioned before, the units were changed and named the Bel and the Néper, the following formulæ applying :—

$$\text{Bel} = 2 \log_{10} \frac{I_1}{I_2} \qquad \text{Néper} = \log_{\epsilon} \frac{I_1}{I_2}$$
$$= 2 \log_{10} \frac{V_1}{V_2} \qquad = \log_{\epsilon} \frac{V_1}{V_2}$$
$$= \log_{10} \frac{P_1}{P_2} \qquad = \tfrac{1}{2} \log_{\epsilon} \frac{P_1}{P_2}$$

The Decibel or " db " which is the tenth part of a Bel is now the unit most used and is exactly the same as the obsolete Transmission Unit.

TABLE I.

	Bel	Decibel	Néper	TU	βl	BSM	MSC
Bel ..	1·0	10·0	1.15	10·0	1·15	10·844	10·56
Decibel ..	0·10	1·0	0·115	1·0	0·115	1·0844	1·056
Néper ..	0·8686	8·686	1·0	8·686	1·0	9·42	9·175
TU.. ..	0·1	1·0	0·115	1·0	0·115	1·0844	1·056
βl	0·8686	8·686	1·0	8·686	1·0	9·42	9·175
BSM ..	0·0923	0·923	0·1062	0·923	0·1062	1·0	0·974
MSC ..	0·0947	0·947	0·109	0·947	0·109	1·0267	1·0

Multiply the units in the vertical column by the ratio shown to obtain the units in the horizontal line.

The multipliers giving the relations between MSC and the other units are based on the American standard cable having zero inductance and leakance. For the English cable (MSC) the values in the horizontal line should be reduced by 3 per cent. and those in the vertical column should be increased by 3 per cent. The unity figure is, of course, excepted.

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Fig. 1 shows the value in Decibels and Népers of various values of power, current and voltage ratio.

Other Transmission Measurements.

There are two other transmission measurements which may be made with apparatus, the same or similar to that used for the measurement of transmission gains and losses. These are Level and Turnover measurements.

Level Measurement.

It will readily be appreciated that in any system conveying energy or matter, in which attenuation or loss occurs one may consider the system to experience a continuously decreasing power or quantity level as one proceeds from the input to the output end. Now, in an electrical transmission system there is continuous loss of energy and as a result of this there is a continuous drop in level.

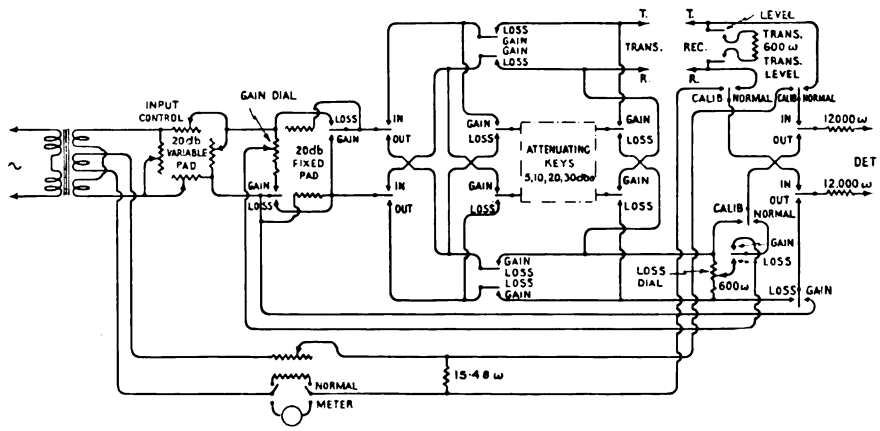

Fig. 3.

Obviously if we can measure level we shall have a very ready means of determining whether any part of our lines or apparatus are overloaded and whether a leakage or reflection of energy is taking place. Such a measurement also provides a ready guide for manual or automatic control of output at the point of junction of two trunk lines or between a trunk line and a radio system in order to compensate for changes in the length of the incoming trunks and for differences in speakers' voices and/or microphones. Such an arrangement enables a long distance circuit, including cables, repeaters, radio, etc., to be worked under the best operating conditions peculiar to each part, level adjustments being made at each junction.

In measuring any quantity, as distinct from a ratio, some point of reference is required, and level is measured with reference to an arbitrary point known as *zero level*.

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Unfortunately there are several values of zero level used for different purposes, but probably the best is the zero level of one milliwatt. If the power passing a given point in a transmission system is one milliwatt the level is said to be *zero level*, and levels above and below zero are measured in Bels and Népers. It must be remembered that level is normally a power measurement and the formulæ are therefore :—

$$\text{Change of level} = 10 \log_{10} \frac{P_1}{P_2}$$

$$\text{Level} = 10 \log_{10} \frac{1}{W}$$

where W is the power in milliwatts at the point at which the level is being measured.

Of course level may be measured or spoken of as a voltage or current level, but in such a case the fact should be specified to avoid confusion. Since the above formulæ are derived from the attenuation formulæ, a positive result is a loss, and a negative result represents a gain, but when referring to level one speaks of a point which is higher by n db, as being at a level of $+ n$.

Turnover.

Turnover is lack of balance of the various parts of a line or apparatus to earth and is so called because it may be detected by reversing or turning over one end of a line and making transmission measurements in the two conditions.

An oscillator having an unbalanced output circuit will often suffer from turnover which causes one half cycle to differ from the other, thus producing the effect of a symmetry.

Perhaps the most serious trouble caused by lack of balance is the transfer of energy from one telephone line to another or to a telephone line from a neighbouring telegraph or power line. This is known as crosstalk and manifests itself in the form of unwanted speech or noise on the line. A clear division between the cause and the effect should be made. Both may be measured, the cause (unbalance) in micro-farads, henries and/or ohms according to its nature, or (turnover) in Bels or Népers, and the effect (crosstalk) may be measured in crosstalk units. 1 CTU exists when the energy transferred to another circuit is $1 \cdot 10^{6}$ of the power in the exciting circuit, and the result of crosstalk which is noise, may be measured as a level, also in terms of Bels and Népers.

The Marconi Transmission Measuring Set.

A Transmission Measuring Set has been developed for the purpose of measuring the transmission characteristics of lines and apparatus having an impedance of 600 ohms, and has the following ranges.

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The set will measure Gains from 0 to 70 decibels, Losses from 0 to 70 decibels, and Levels from −70 to +20 decibels.

Turnover measurements may also be carried out and these measurements are explained later on. It should be pointed out that the set can also be designed to measure lines or cables other than those of 600 ohms impedance, although the majority of cables have an impedance of the latter value. The error caused by using a 600 ohms set to measure cables of impedances other than 600 ohms is discussed later.

Fig. 2 is a photograph of the Transmission Measuring Set, which consists of the following visible parts :—

A. Loss Dial.
B. Gain Dial.
C. Keyboard.
D. Input Control.
E. Meter Key.
F. Meter.
G. Calibration Control.
H. Compartment for plugs and cords.

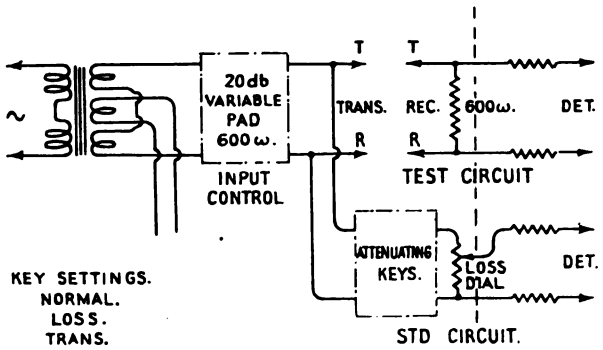

FIG. 4.

The following keys are provided on the keyboard, reading from left to right :—

Top Row.

1. The Normal-Calibrate key which is used to bring the measuring or the calibrating circuits into use.

2. The Gain-Loss keys which are operated together by means of a bridged handle and which converts the circuit from the Gain to the Loss measuring condition.

3. The Transmission-Level key which changes the circuit to provide for the measurement of transmission gains or losses and levels.

Bottom Row.

1. The 5 and 30 Decibel key for inserting an attenuating pad of either 5 or 30 Decibels into the standard circuit.

2. The 20 and 10 Decibel key for inserting an attenuating pad of either 20 or 10 Decibels into the standard circuit.

3. The In-Out key for comparing the circuit under test with the standard. The key is marked IN-OUT because the instrument virtually measures the ratio of input to output, the two tones being equalised for balance in the detector circuit by the insertion of the variable standard loss.

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Inside the instrument is mounted an input transformer, various attenuating pads, and potentiometers and resistances.

The schematic diagram is shown in Fig. 3, from which it can be seen that the method of measurement adopted is one of comparison with standards included within the instrument. The question of difference in phase between the output potential of the circuit under test and that of the standard is one which may be neglected since the outputs are connected alternatively to the detecting device, which may be either a telephone receiver or a valve voltmeter. Since in either case only one potential is applied at a time it is necessary only to compare the RMS voltages produced without reference to any change of phase.

Referring to the circuit diagram, and reading from left to right, the input transformer which has an input impedance of 600 ohms feeds energy into the measuring circuit and/or the calibrating circuit. The measuring circuit will now be considered.

This circuit includes a variable 20 db pad, known as the input control, which enables the energy in the test and standard circuits to be altered without changing the energy level in the calibration circuit, since its input and output impedance are constant, only the attenuation being variable.

The next item is a fixed 20 db pad, of which the Gain Dial forms a part, which is only used for gain or positive level measurements. Here the circuit splits and the energy passes (A) to the " TRANS." terminals and so to the test circuit, and

(B) to the Loss Dial or standard circuit.

The two attenuating keys will be in the (A) path when measuring gain and in the (B) path when measuring loss.

From the test circuit the energy passes through the " REC." terminals to the detector and from the loss dial also to the detector. The detector circuit, consisting of two high resistances and either a Bell receiver or a valve voltmeter, is connected to only one of the (A) and (B) circuits at one time. The total impedance of the detector circuit is not less than 24,000 ohms and therefore the effect produced by its presence is entirely negligible.

The forgoing remarks should make clear the fact that the test and standard circuits receive the same input and therefore that if the output balances the loss or gain in each side must be equivalent.

When measuring loss, a loss in the test circuit is balanced by a known added loss in the standard circuit, and when measuring gain, a gain in the test circuit is balanced by a known added gain in the standard circuit and, if necessary, by a known added loss in the test side as well.

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The calibrating circuit is discussed under the heading " Calibration."

It will be noticed that there are two main circuit conditions, viz., those for measuring loss and gain.

Loss Measurements.

It will be seen from Fig. 4 that, with the aid of the " IN-OUT " key, the input voltage is applied to the circuit under test and to the standard, the detector circuit, shown to the right of the vertical line, being transferred to the output of each circuit in turn. The keys should be set as follows for making loss measurements :—

" Calib-Normal " key to " Normal."
" Gain-Loss " key to " Loss."
" Trans-Level " key to " Trans."

If, now, with the circuit to be tested connected as shown in Fig. 5, the " IN-OUT" key is operated from one position to the other a change in volume will be heard in the receiver or a change in deflection will be noticed on the valve voltmeter. The loss dial which reads from 0 to 20 Decibels in steps of 0·5 db., and, if necessary, one or both of the attenuating keys should be adjusted until a balance is obtained with the key in the " IN " and " OUT " positions.

The loss inserted between the transmitting and receiving terminals is then equal to the sum of the losses indicated on the loss dial and the attenuating keys.

For reasons which will be explained under " Turnover," the " tip " and " ring " terminals should be joined respectively together through the line or apparatus under test, that is to say, tip should be joined to tip and ring to ring. Fig. 5 shows the correct and the incorrect methods of joining the circuit to be tested to the terminals of the set. If it is not possible to verify this, a further test should be made with the leads at one end reversed and the mean of the readings should be taken.

The input level when measuring loss with the set correctly calibrated is zero level.

Gain Measurements.

The circuit arrangement for gain measurements is shown in Fig. 6 from which it is obvious that the input energy after passing the input control pad is first attenuated by 20 db in the fixed pad and that further attenuation may be added by means of the attenuating keys, if required, before it passes to the input of the circuit under test. The keys should be set as follows :—

" Calib-Normal " key to " Normal."
" Gain-Loss " key to " Gain."
" Trans-Level " key to " Trans."

The " IN-OUT " key when in the " IN " position enables the output from the " test " circuit to be ascertained. When the key is thrown to the " OUT " position

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the detector is connected across the gain dial, which forms part of the 20 db fixed pad, in order to measure the input, attenuation being added to balance the tones in the receiver by adjustment of the dial. When the dial is all included in the circuit, that is to say when the slider is at the top in Fig. 6, the energy level at the input to the standard circuit is 20 db higher than at the input to the test circuit so that, provided the gain tc be measured is not more than 20 db it may be measured on the gain dial. If the gain exceeds 20 db the attenuating keys must be used. These insert pads immediately before the test circuit, thus cutting down the input level as well as assisting in the measurement. This is an advantage as it prevents the output level from rising above zero level and possibly overloading the amplifiers or repeaters in the test circuit which, by causing distortion, would produce inaccurate gain readings. It is apparent that by varying the position of the slider on the potentiometer forming the gain dial, and by adjustment of the attenuator keys, the ratio of input potential to output potential of the standard circuit is varied and may be adjusted until it is equal in the two positions of the "IN-OUT" key, in which case the gain is equal to the sum of the gain dial and attenuating key readings.

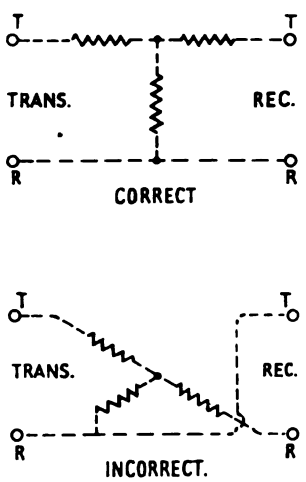

FIG. 5.

The input level when measuring gain with the set correctly adjusted is $-$(20 db + the sum of the attenuating key settings).

Calibration.

Calibration is only necessary when tests are to be made with a definite input current or input level. The normal level for making transmission measurements is "Zero level." The value of zero level has several definitions and as many values, which are used for different types of measurements or for measurements on different apparatus as has been explained. The value of zero level commonly used for measurements on lines and cables for voice frequency telephony is one milliwatt, *i.e.*, when a power of one milliwatt is being fed to a line it is said to be working with an input of zero level.

It is necessary during calibration so to adjust the apparatus that the input current to the circuit under test is at a level of one milliwatt or zero level. To enable this to be done, an additional winding, the tertiary, is provided on the transformer, together with a meter and key and several fixed and variable resistances. The meter key is arranged to insert the meter in circuit in place of the protective

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resistance of equal value which replaces the meter when the latter is not required, and which can be used to switch off the meter quickly in the event of the current rising too rapidly. The meter is, however, of a fairly robust nature. To calibrate the set the keys must be set as follows :—

" Calib-Normal " key to " Calib."
" Gain-Loss " key to " Loss."
" Trans-Level " key to " Trans."

Then with both the attenuating keys in their zero positions the meter key is pulled and the calibration adjustment knob is rotated to adjust the meter reading to 50 m.a. in which condition the potential drop across the 15·48 ohm resistance (shown in Fig. 7) is the same as that across the input end of a 600 ohm line having an input of zero level.

Now, if the " IN-OUT " key be thrown backwards and forwards, a difference in volume will be heard in the receiver. This difference should be equalised by adjustment of the input control knob, *i.e.*, the 20 db variable pad, which controls the amount of energy passing to line. When a balance has been obtained the circuit is correctly calibrated and the input and calibration controls should not be altered. The meter should be watched to see that the current remains at 50 m.a. It is, of course, necessary to recalibrate the set when the frequency is changed.

Calibration at Levels other than Zero Level.

If it is desired to operate the set at levels other than zero level the current in the calibration circuit may be set to a predetermined value other than 50 m.a.

The formula is given below :—

$$\text{Meter reading} = 50 \sqrt{\text{Level}}.$$

The meter reading is to be expressed in *milliamperes* and the level required in *milliwatts*. Thus a level of 2·25 milliwatts is the highest which can be used with the existing meter having a maximum reading of 75 milliamperes.

For gain measurements a higher input level may be obtained, if required, by the simple expedient of calibrating the set with the attenuating keys adjusted to the required number of decibels and then re-setting the keys to the zero position before making measurements. In this case the input level will be —(20 db—the sum of the attenuating key readings as set during calibration) and the meter should, of course, be adjusted to 50 milliamperes in the ordinary manner. If the attenuating keys are changed from the zero position during measurement the formula for the level is —(20 db - calibration setting of keys + measuring setting of keys).

In this connection a table of levels showing the relation between decibels and milliwatts will be found useful. (See Table II.)

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The Measurement of Apparatus having Impedances other than 600 ohms.

The set may be used to measure apparatus having impedances other than 600 ohms and the errors will not in general be great.

TABLE II.

INPUT LEVEL.

Decibels.	Milliwatts.
0	1·0
1	1·259
2	1·585
3	1·995
4	2·512
5	3·162
10	10·0
15	31·623
20	100·0

Alternatively, two transformers having an impedance of 600 ohms for one winding and the other of the impedance of the apparatus to be measured may be inserted between the TRANS.-REC. terminals with the new value impedance windings joined, and the loss measured. Then the apparatus to be measured is inserted between the transformers and the total loss is measured.

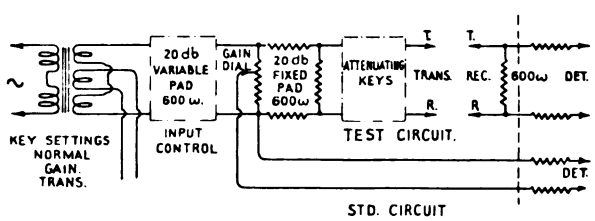

FIG. 6.

The loss in the apparatus is the total loss minus the loss in the transformers. It should be understood that where the impedance is not 600 ohms, the input level will be altered.

Measurement of Level.

Level measurement differs from other measurements in that only the point of the line at which the level is required is connected to the set.

The point to be tested is connected to the REC. terminals and the circuit is tested in the ordinary manner, the level being read from the Loss Dial and attenuating keys. The circuit conditions are exactly as for making transmission measurements save that the 600 ohms terminating resistance across the REC. terminals is removed. The keys should be set as follows :—

" Calibrate Normal " key to Normal.
" Gain Loss " key to Loss.
" Trans-Level " key to Level.

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Positive levels are measured by calibrating to, say, 20 db above zero level and measuring on the loss dial. The calibration is carried out by setting the attenuating keys to 20, and adjusting for balance. The measurement is then made with the attenuating keys returned to normal. The level, being measured, then equals (20 — setting on dial — setting on attenuator keys).

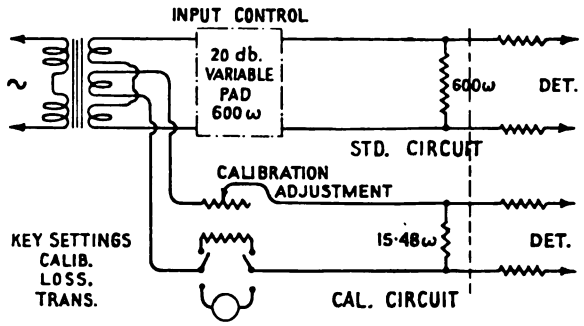

FIG. 7.

It will be noticed that the attenuating keys have no effect when measuring positive levels.

Method of Checking the Accuracy of the Transmission Measuring Set.

The set may be checked at any time by joining the TRANS. and REC. terminals together when upon making measurements Zero Gain and Zero Loss readings should be obtained.

To check the attenuating keys and the other parts of the dial scales the terminals should be joined through known attenuating pads and measurements made. Values for a few square π pads are given in Table III.

TABLE III.

Decibels.	Series Arms.	Shunt Arms.
5	182·3 ohms	2143·0 ohms
10	428·45 ,,	1156·0 ,,
20	1483·0 ,,	733·5 ,,
30	4739·5 ,,	639·3 ,,

Should there not be sufficient resistance available to form pads, a check may be made with a single resistance box which should be connected in shunt with the TRANS. terminals.

Appropriate values of resistance are given in Table IV.

TABLE IV.

Decibels.	Resistance.
1	2400 ohms
2	1120 ,,
3	720 ,,
4	510 ,,
5	390 ,,
10	140 ,,
20	33 ,,

O. S. PUCKLE.

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MARCONI NEWS AND NOTES

MARCHESE MARCONI ELECTED PRESIDENT OF ITALIAN ROYAL ACADEMY

THE many friends of Marchese Marconi, in all parts of the world, will be gratified to learn that he has received a further honour from the King and people of Italy in being appointed a member and President of the Italian Royal Academy.

This appointment followed a special vote taken at a meeting of the Academy on September 19th, in accordance with which Signor Mussolini submitted two decrees to the King of Italy, one appointing Marchese Marconi a member of the Academy, and the other conferring upon him the Presidency, in succession to Signor Tittoni, who has resigned on account of ill-health. These decrees were immediately approved by the King, and published.

Marchese Marconi has been a Senatore of Italy since 1914, and received the title of Marchese in June, 1929. He holds a number of other Italian honours and decorations, and amongst the honours conferred upon him by other countries is an honorary British Knighthood by the award of the Grand Cross of the Victorian Order in July, 1914.

World Power Conference, 1930.

Engineers from all over the world assembled at the second World Power Conference, held in Berlin this year.

A special feature of the Conference was a series of addresses by distant speakers, the addresses being simultaneously conveyed to Berlin and to the National Electric Light Association Convention in San Francisco. Marchese Marconi spoke from London. Lord Derby also spoke from England. Thomas A. Edison, Owen D. Young and Mathew Sloan spoke from the United States; and Dr. Carl Koettgen and Dr. Oskar Von Miller from Germany.

In the course of his address, Marchese Marconi referred to the participation of distinguished speakers in various separate and distant parts of the earth in the two conferences, and said: "This participation has been made possible by the great advances in radio and telephonic communication which have now come into active being, and which have already linked up the world in a way which was never experienced before."

Chairman's Letter to Marchese Marconi.

As a sequel, the following letter was sent by the Chairman of the World Power Conference to Marchese Marconi:

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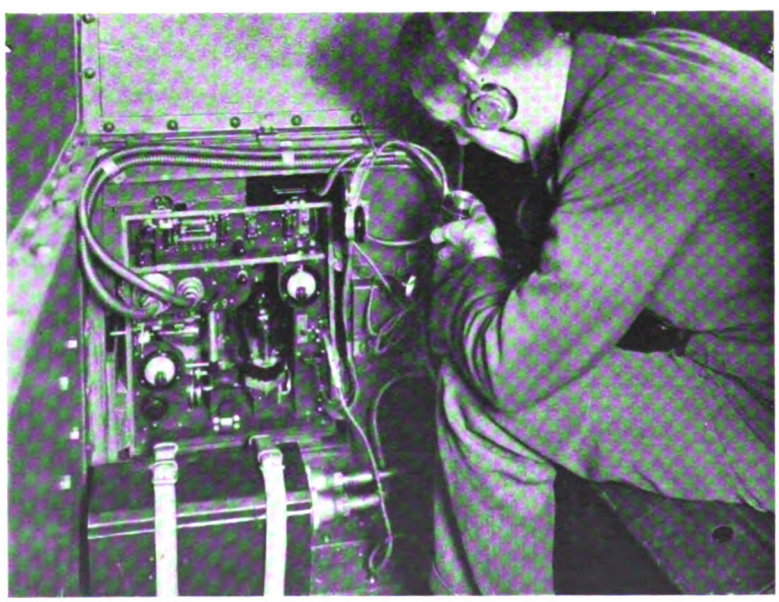
" It is our privilege and great pleasure, in the name of the German Committee for the Second World Power Conference, most warmly to thank you for kindly co-operating in the tele-communication effected on June 18th at the occasion of the World Power Festival. The fact that you, to whom humanity owes the great blessing of radio-telegraphy, participated in person in this memorable radio-phonic conversation, fully enhanced its historic significance, and greatly added to the thrill of the occasion. The acoustic reception of all speeches of this five-cornered radio conversation was quite perfect. Among the four thousand listeners in the banqueting hall, our Italian friends certainly had the greatest right to be proud of their compatriot, but it is true that all the prominent engineers, representing fifty nations, when hearing your voice, whole-heartedly united in the feeling of vocational pride in the great feat which was made possible through your genius.

" By your kindness you have greatly contributed towards the success of the Second World Power Conference. For this we would cordially thank you. We feel, however, that our thanks can but be a small expression of what the world owes you for alleviating its troubles and opening up a new era of international understanding and amity."



Special Marconi equipment installed in a Vickers-Armstrongs' Tank.

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Wireless for Mechanised Armies.

The difficult problem of communicating over short distances from tanks and other armoured fighting vehicles has been satisfactorily met by Marconi's Wireless Telegraph Company, Ltd., who have developed for this purpose a special wireless set known as the Type S.B.1a.

It is an ultra short-wave portable installation—operating on between 7 and 8 metres—designed for wireless telephony and telegraphy to be used either as a permanent fitting in armoured vehicles or as a portable set for trench and other advanced military positions to which it can easily be carried.

The aerial is almost invisible and consists of a copper plated steel rod twelve feet in height and made in four sections. In use it is liable to be subjected to severe swaying and bending, but it is designed to be very flexible and will not buckle.

A feeder cable connects the transmitter to the aerial system which is connected to the body of the tank or to "earth" through a balancing coil so as to permit the maximum amount of energy to be transferred to the aerial for the wavelength in use.

Protection from Shocks.

The transmitter and receiver are compactly fitted in a teak instrument case and are very simple and easy to operate. When the set is fitted in a moving vehicle where jars and shocks would cause damage, these vibrations are eliminated by shock-absorbing slabs of sponge rubber.

Power for the transmitting valves is supplied by a rotary transformer, driven by a 12-volt accumulator, and delivering 600 volts to the anodes.

For telephony the choke control system of modulation is used, and for telegraphy an interrupter disc mounted on the shaft of the rotary transformer enables the tonic train system of transmission to be employed. Four valves are used in the transmitter, two oscillators and two modulators, and four valves are used in the receiver, the last two stages being note magnifiers.

Dual Control and Intercommunication.

An interesting innovation for land vehicles is the system of intercommunication and dual control which was previously confined to aircraft apparatus. This allows the wireless apparatus to be switched off and two people in the vehicle to communicate with each other by means of the telephones, or, alternatively, either of them can operate the wireless equipment. When communicating with each other the last two stages of the receiver are brought into use as speech amplifiers.

Wireless Telephony for Ships' Trials.

An important feature of the recent trial trip of the new White Star Liner "Britannic" was the use of Marconi wireless telephone sets fitted on board and in

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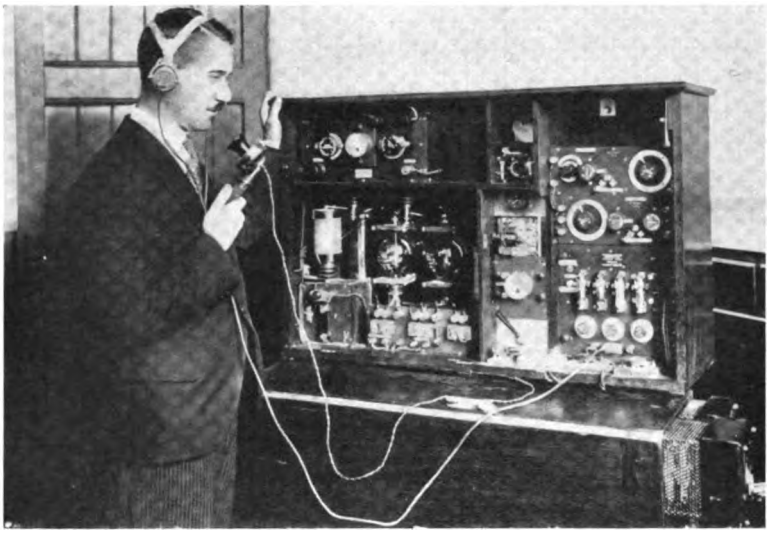

Speaking by Marconi Wireless Telephone from Messrs. Harland and Wolff's offices at Belfast to the M. V. " Britannic " on trial in the Clyde.

the builders' offices to enable the observers and engineers at sea and ashore to keep in constant communication.

This was the first time that the wireless telephone was used in connection with a ship's trials, and the innovation proved of such value in exchanging reports of the performance of the new ship that as soon as the trip was completed Messrs. Harland and Wolff, the Builders, applied to the Post Office for permission for similar facilities for the " Innisfallen," which they had just constructed for the City of Cork Steam Packet Company. Sanction was given, and the utility of the Marconi telephone was again so marked that the installation of this equipment may become an important factor in ships' trials in the future.

The trials of the " Britannic " and the " Innisfallen " were held in the Clyde estuary, at a distance up to 150 miles from the builders' yards, and immediate communication was maintained throughout the trips, thus effecting a very valuable saving of time and expense in many particulars.

The telephone equipment fitted on these vessels and at Messrs. Harland and Wolff's offices at Belfast was installed by the Marconi Company, and is known as the Marconi Type Y.C.4. It is a combined transmitter and receiver instrument, the former having a power of 500 watts.

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THE MARCONI REVIEW

October, 1930

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THE MARCONI REVIEW

No. 25. *October, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

DESERT MOBILE WIRELESS TELEGRAPH STATIONS FOR THE EGYPTIAN GOVERNMENT

Mobile radio stations have been employed for many years for military services, but it is now becoming generally recognised that this type of installation has a much wider field of usefulness, a case in point being the mobile stations mounted on six-wheeled chassis which are being supplied by Marconi's Wireless Telegraph Company to the Egyptian State Telegraphs and Telephones Administration.

THE Land of Egypt embraces over 600,000 square miles of the earth's surface, an area more than six times as large as the British Isles, of which, however, only a small part, less than one-thirtieth, can be cultivated, the rest being almost waterless desert, across which humble camel caravans plod for weeks at a stretch.

Of the three Egyptian deserts, the smallest is the Wilderness of Sinai, which, about as large as Scotland, is a rocky and mountainous peninsula, rich in minerals, rising to a high, central wind-swept plateau called *Gebel Tih* or the "Desert of Wanderings."

The Arabian Desert, including Nubia, is likewise a place of high, barren mountains rising clear-cut, peak on peak, into the blue distance and honeycombed with the ancient gold-workings of the Pharaohs. The Arabian Desert is in Egypt, not Arabia, from which it is separated by the Red Sea. Herodotus first called it so, and the name has persisted.

Near the Mediterranean littoral the great Libyan Desert, the eastern and most inhospitable part of the Sahara, divided from the Arabian Desert by the Nile, consists of a desolate stone-littered plateau, changing further south to huge areas of fantastically eroded arenaceous rocks, while, still further south, where all the sandstone has been blown away to form dunes, there is a dreadful country of dazzling white

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chalk, geologically the same age as the Hampshire Downs, where the weary travellers as they trudge forward under the burning sun are wrapped in clouds of choking dust as with a mantle.

Hidden away securely in the eternal and petrified confusion and chaos of the great Libyan Desert are a number of deep and broad hollows containing fertile oases, supporting large populations, where a myriad crystal springs gush forth from the ground. These oases, all of which are guarded by tremendous limestone cliffs, are not only exquisitely beautiful but are famous in history. Herodotus called them " The Islands of the Blest."

The Egyptian Government is about to install fixed wireless stations at Dakhla, the Great Oasis of the Interior (pop. 20,000) ; Siwa, the Oasis of Jupiter Ammon (pop. 5,000) ; and Baharia, or the Oasis of the North (pop. 500) ; and is also putting into service mobile stations mounted on six-wheeled chassis. The control station will be at Cairo, near the Great Pyramids.

Mobile Equipment.

The mobile stations are equipped with both medium and short wave installations. The wave ranges are :—

Short wave transmission, 20/50 metres
Short wave reception, 20/75 metres
Medium wave transmission, 600/2,150 metres
Medium wave reception, 300/10,000 metres

These wave ranges were chosen by the Egyptian State Telegraphs so as to cover every exigency of service which the stations may be required to provide, including emergency ship-to-shore work, medium and short wave point-to-point communication, aircraft work, topographical survey, Frontiers defence and desert patrol communication duties.

The short wave transmitters are of the ZSB2 type, coupled, 100 watts rating, and employ rotary transformers worked from storage batteries. These transmitters are extremely robust and reliable. Associated with the ZSB2 transmitters are type AD20 short wave receivers, employing the latest screened valve circuits and designed to secure great sensitivity with maximum stability and ease of operation.

The short wave emissions are radiated from single wire drum-supported aerials at the top of 30 feet masts, the aerials being adjustable to one-quarter or one-half the wavelength on which it is desired to emit signals.

The short wave transmitters in the oases with which the mobile short wave transmitters will correspond are the simple and efficient Marconi type S100 quarter-kilowatt undriven sets, mounting copper-shielded valves and having a wave range of 15/20 metres.

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The optimum short waveband for communication in the Egyptian deserts has been found to lie between 37 and 41 metres.

Medium Wave Apparatus.

The medium wave transmitters for the mobile stations are the UC2 half kilowatt self-contained models. Rectifying valves are not used in these sets, energy being derived directly from 3,000 volts d.c. generators. Single inductance-units provide the required wave range.

For medium and long wave reception RG19a receivers have been installed. These instruments cannot be surpassed in performance by any general purpose receiver known, yet are extremely easy to operate. The tuning elements of the RG 19a receivers consist of four valve-coupled cascade circuits, operated by limited gang-control. The two high frequency amplifiers provide an overall magnification of from 500 to 1,000 times, controllable by resistances placed in series with the screened valve filaments. Both tuners and amplifiers are housed in very robust cases and are supported on shock-absorbers.

The independent power units are simple lightweight water-cooled petrol-electric sets, driving double-output two-field generators, which give 22 amperes at 12/16 volts and 300 milliamperes at 3,000 volts. Provision is also made for the charging by means

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of these generators of the power storage batteries with which the mobile stations are equipped, which consist of 36 volts 100 ampere hours lead acid shock-proof unspillable accumulator sets.

Normally these cells illuminate the mobile wireless office, but a switch enables the car-lighting battery to be used at will.

Special skids are provided for lowering and raising the generator sets from and into the vans. These skids are employed as bases for supporting the generators when they are being used on soft or sandy ground.

The two 70 feet sectional masts together with the short-wave mast are carried on the roof of the van.

Every component liable to damage by vibration and shock has been carefully sprung, " Sorbo " rubber pads being largely employed for this purpose.

Chassis.

The specification of the six-wheeled pneumatic tyred chassis, conforming generally to the requirements of the Egyptian Frontiers Administration, embodies an exceedingly robust four-cylinder engine giving 35 b.h.p. at 2,500 r.p.m., mounted in a light but immensely strong deep-section channel frame of special alloy steel 17 feet $2\frac{1}{2}$ inches long, with 12 feet wheel base and 4 feet 8 inches track. Two gear boxes provide the vehicle with eight forward speeds. With the engine running at 3,000 r.p.m. the road speed on lowest gear is $3\frac{1}{2}$ miles an hour. On top gear 4 miles an hour can be maintained. The chassis in addition carries a special winch and steel cable operated by the driver, by means of which the vehicle may be extricated from deep, sinkages, while for exceptionally severe conditions such as dunes or stretches of loose sand, caterpillar tracks are provided. The main petrol tank capacity is 17 gallons, and there is also a reserve tank holding a similar amount, transfer being by means of engine-operated pump. A large water-tank is also carried. The chassis-weight has been kept down to two tons.

Bodies.

The detachable bodies are made of reinforced teak and are double, the space between the inner and outer shells being filled with cork-dust after the manner of a refrigerator, thus ensuring protection from the African sun for the operator and his gear.

The wireless bodies are entirely independent of driving cabs and bearers, and are provided with an arrangement by which they can be easily lifted from the chassis, leaving the chassis with cab and bearers, free to receive another type of body, so that when the wireless apparatus is about to be stationed for some time at a particular point the chassis can be released for use elsewhere.

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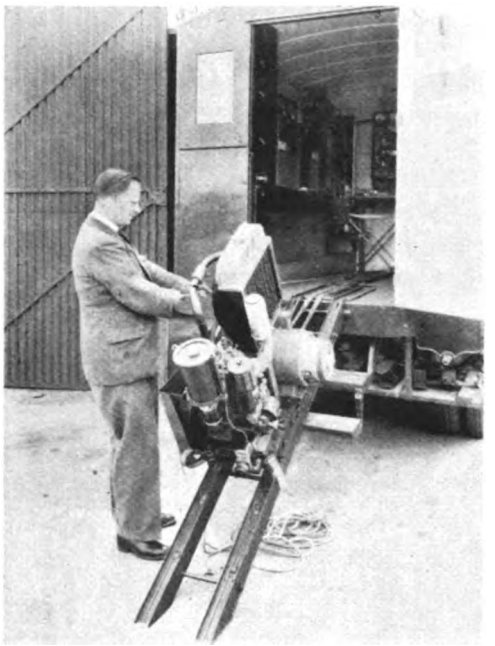
Every year, at the period when the moist westerly gales sweep down the Mediterranean from the Atlantic, deep depressions are formed in the atmosphere over the sea. The heated air over the deserts rushes in to fill up these depressions and sets up fierce dust storms in the Libyan Desert which rage for days at a time. To meet this situation the bodies are arranged so that they can be closed up hermetically. The complete body with wireless generator weighs 11 tons.



Services Required.

One of the most important functions of the mobile sets will be to maintain communication between the Egyptian Royal caravan and the Egyptian capital when H.M. the King Fouad goes out into the deserts to visit those of his subjects who live there.

Some idea of the exacting conditions the mobile sets have been designed to meet may be gathered from the fact that they will have to cross the great lines of sand-dunes 300 feet high which stretch N.E. and S.W. across the face of the Libyan Desert for hundreds of miles and to accompany the Royal caravan to the Oases. The Egyptian Oases are guarded by cliffs a thousand to fifteen hundred feet high. Entrance to and exit from some of the oases is by means of a precipitous and dangerous pass which the lorries will have to negotiate.

Again, in some of the *wadis* of the Arabian Desert the summer noon temperature reaches 140° Fahr., whilst at some points on the Red Sea littoral the atmospheric humidity is 95%. In contrast to these conditions, snowstorms occur in winter on the Sinai peninsula, and on the mountain road leading to the famous monastery of Saint Katherina founded by the Roman Emperor Justinian, the temperature sometimes falls to 15 degrees below freezing point.

Desert Wireless Patrols.

The oases of the Libyan Desert are connected to each other and to the Nile Valley by tortuous tracks, worn smooth through the ages and lined with the skeletons

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of countless camels which have perished on the weary trek. One of these ancient trails, known to the Bedouin as *Darb el Arbain*, or " The Forty Days' Road," stretches from Darfur and Dongola in the Anglo Egyptian Sudan to Khargha, the Great Oasis of the Exterior, and thence to the Nile Valley near Assiut. Another equally old route is called *Darb el Towil*, or " The Long Road," and leads from Dakhla Oasis to Beni Addi on the Nile Valley.

It was along these ancient desert roads that vast quantities of spices and gums and great numbers of slaves were brought into Egypt in olden times, and they are still used by the camel caravans which come up from Morocco and Cyrenaica. In these caravans, which may consist of a thousand camels laden with merchandise, there are sometimes concealed international drug smugglers, disguised as simple caravaneers, and the new mobile wireless sets will enable the Egyptian Frontiers Administration patrols out in the desert to keep in touch with the police in Cairo and with the Customs officers in the Libyan oases through which the caravans must pass to obtain food and water, so that more effective steps can be taken to eliminate the traffic in cocaine, opium and hashish.

It is also proposed to employ the mobile sets to aid the Survey of Egypt parties working in the great Qattara Depression ; an immense hollow in the Libyan Desert, 7,000 square miles in extent, commencing 120 miles west of Cairo, and stretching nearly to Siwa Oasis, into which it is hoped one day to admit the Mediterranean Sea, by means of a tunnel, thereby creating an inexhaustible supply of cheap hydro-electric power and rendering Egypt independent of imported fuel supply.

H. WATTERSON.

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THE MARCONI DORY TRANSMITTER

This Transmitter has been designed for the purpose of assisting small dories leaving the parent ship in such a way that in the event of an accident or the impossibility of the dory being able to return to the parent vessel, the Transmitter can be used in the emergency and the Direction Finder on the parent ship can be used as a method of orienting the position of the dory.

THE Transmitter consists of a small watertight box approximately 18 in. by 8 in. by 9 in., provided with canvas flaps, and so designed that it can be slung under the seat of the dory in special metal brackets supplied for this purpose.

The Transmitter is a self-contained unit, carrying in its box a 6-volt jelly electrolyte accumulator as a source of power. This type of accumulator has been adopted so that in rough weather there will be no possibility of electrolyte being spilt inside the Transmitter and so damaging any of the essential parts.

Circuits.

The circuits consist of a small plain gap Transmitter with an associated closed oscillatory circuit consisting of a fixed condenser and variable inductance. This closed circuit can be tuned to any wavelength of the order of 180 to 300 metres, dependent upon the size of the aerial used in the dory. The aerial circuit is coupled directly to the closed circuit and an additional lengthening coil included so that the specified wavelength may be tuned without any fine tuning arrangements such as variometers, etc.

All the apparatus is totally enclosed in the watertight box, the only exposed terminals being the aerial and earth terminals.

Keying.

A special feature of this Transmitter is the fact that it is foolproof, both from the point of operation and from the point of keying. It is appreciated that the personnel who will handle this Transmitter have no knowledge of the morse code, and to provide for this keying is accomplished by the slow rotation in a clockwise direction of a small handle which carries a wheel, the periphery of which is cut in such a way as to carry a letter, and this letter is then followed by a long dash. The letter is chosen to designate the particular dory on which the Transmitter is fixed, and the object of following up this letter by the long dash is that once the operator of the parent ship hears the dory calling, he knows the particular dory from the letter transmitted, and the long dash enables him to take an accurate D.F. bearing on the position of the dory.

In actual operation it is essential to press a small switch on the end of the Transmitter in order to complete the circuit with one hand, and to rotate the handle of the transmitting wheel slowly with the other.

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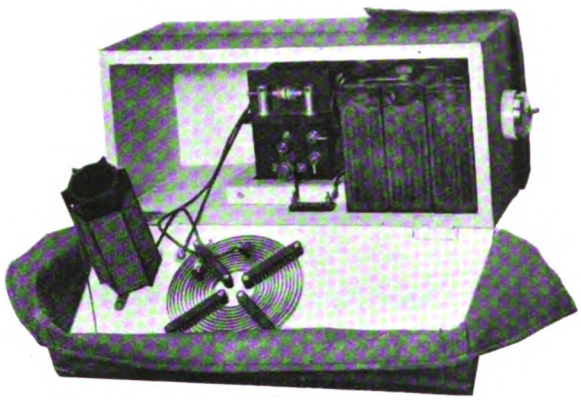
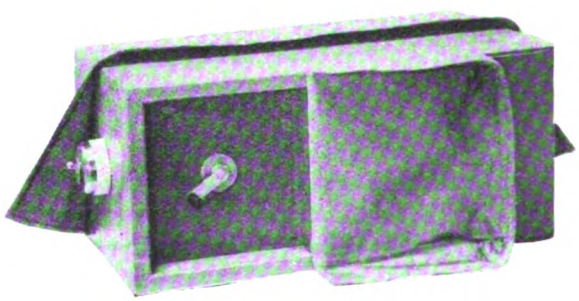
Adjustments.

All adjustments are made by the Wireless Operator on the parent ship before the dory leaves the vessel. They consist of determining the wavelength which is to be used by the group of dories, tuning the enclosed circuit to this wavelength, and regulating the aerial circuit to interresonance with the particular closed circuit wavelength chosen. The only possible adjustment other than this that might be



required from the Operator is the adjustment of the make and break on the induction coil. This make and break is specially designed to give almost continuous working over an indefinite period, provided the contacts are kept reasonably clean. Spare contacts and springs are provided with the Transmitter, but these contacts should only be adjusted by the Wireless Operator in charge of the parent vessel.



Range.

The Transmitter gives approximately ·3 amps. in an average dory aerial, and with a modern Direction Finder it is anticipated that this range will be sufficient for 15 to 20 miles good direction finder working.

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Aerials.

The aerial arrangements must be the simplest possible, and it is suggested that one light bamboo pole be utilised at each end of the dory to support a single wire "L" shaped aerial. Insulators can be of the light broadcast "egg" type.

Earth.

The Operator must provide that a reasonable earth connection is made from the earth terminal to a piece of heavy flex, which can either be taken through an earthing bolt on the side of the dory on to an earth plate, or if this is not feasible the heavy flex may be carried over the side of the dory and immersed at least 3 or 4 ft. in the water.

Power.

The power for the transmitter is drawn from a 6-volt 30 ampere hour accumulator, using jelly electrolyte. Under normal conditions there is sufficient power in these accumulators for at least ten hours continuous working.

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THE WARSAW BROADCASTING TRANSMITTER

The new Polish broadcasting station at Rasin, near Warsaw, will be equipped with a Marconi Transmitter Type P.B.3 which possesses several features of more than usual interest.

We may state with confidence that this transmitter presents an outstanding example of super-power broadcasting development in its most modern form, and is one more indication, if such indeed is called for, that British enterprise and industry is not easily to be outpaced by that of any other nation.

THE power of the transmitter to be described below is considerably greater than that of any broadcasting station previously erected, the aerial carrier energy being 120 kw. when adjusted for 80 per cent. modulation, resulting in a C.C.I.R. rating of very nearly 160 kw.

$$(120 \times 1 + \frac{0.8^2}{2} = 158.4).$$

The main power stage of the set employs valves of a new type, capable of greater power input and higher voltage working than has previously been possible with valves of European manufacture.

In general circuit design and in external appearance the Warsaw transmitter closely resembles the installations already operating at Brookman's Park, London, and Stockholm, modified, of course, to suit the increased power rating and the longer wave length, which in this case is adjustable from 1,000 to 1,600 metres, the present wave length allocated to Warsaw being 1,411 metres (212.5 kilocycles).

For purposes of description the transmitter may be conveniently separated into the following component units :-

(1) The Constant Frequency Drive.

This consists of a small receiving type valve in conjunction with a special oscillatory circuit, constructed of particularly rigid components, enclosed in a thermostatically controlled temperature chamber. The precautions taken are such that the frequency of the oscillator is kept constant to about one part in fifty thousand for long periods of time. A precision vernier adjustment of a variable condenser, forming part only of the total oscillatory circuit capacity, enables the frequency to be adjusted within very fine limits, and the circuit being maintained at a constant temperature and calibrated serves as a station wavemeter of a high order of accuracy. The drive itself oscillates at twice the working wave length required and is coupled to a screen grid valve, which acts as a frequency doubler. Three stages of amplifica-

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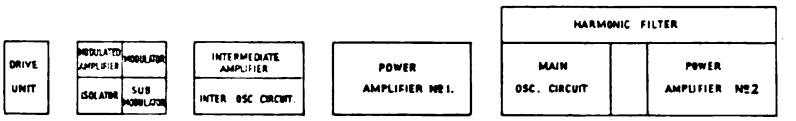
tion including an isolator raise the power level to a suitable value for driving the modulated amplifier.

(2) The Modulated Amplifier and Modulators.

In this unit an amplifier taking an input of 250 to 300 watts is arranged for anode voltage modulation by means of an anode impedance and the operation of a modulator and sub-modulator stage. The design is such that full modulation of the oscillatory output is possible with a grid input to the sub-modulator of approximately 10 milliwatts.



SCHEMATIC LAY-OUT OF BROADCASTING TRANSMITTER TYPE PB3

(3) The Intermediate Amplifier.

Comprised in this unit are eight water-cooled valves (Type CAM.3) of which six are normally in use, the other two being available as spare. Automatic switches connect the grid and filament of these spares into the circuit as soon as the filaments are brought to correct temperature by means of wheel operated rheostats.

This unit is complete with its oscillatory circuit in the one shielded case.

The characteristic of these valves and the negative bias adjustment is such that they operate without grid current even at the maximum voltage swing of the grid input oscillations. The efficiency of the stage is low under such conditions, but on the other hand only a comparatively small power is required to drive it.

The anode input to this stage is approximately 40 kw. and the coupling to the final power stage is accomplished by means of condensers.

(4) The Power Amplifier.

Particular interest centres round the valves in this stage. These are eight in number mounted in sets of four in two frameworks, which are disposed one on each side of a central screened case holding the inductances and condensers forming the main oscillatory circuit. Normally six valves will be in operation at one time, leaving the other two for use as spares.The valves, known as Type CAT.10, are manufactured by the Marconi-Osram Valve Co., and represent a marked advance on previous types. The dead loss rating is set at 50 kw., and the valves are suitable

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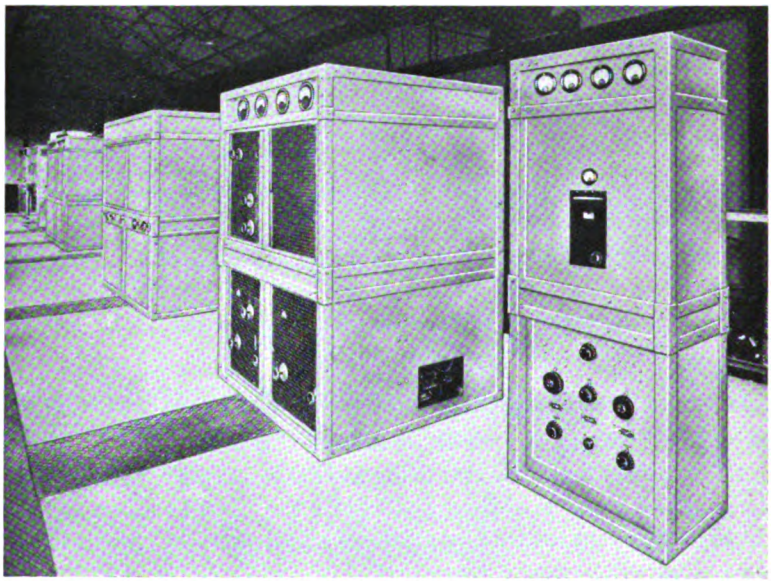
for operating at voltages up to eighteen thousand. The filament current is approximately 225 amperes at about 30 volts, say 6·75 kilowatts, and the emission at this input is of the order of 40 amperes. Each valve is mounted on a wheeled truck or carriage, which facilitates and makes safer insertion or removal from the valve framework.



General View of Set.

At Warsaw it is intended to supply these valves at between fifteen and sixteen thousand volts. The total power input to the anodes required is about 450 kilowatts, which gives an aerial power of 120 kilowatts, and under these conditions a linear response is obtained to applied modulation up to 80 per cent.

Using all the eight valves in this stage it will be possible to generate an aerial carrier power of 160 kilowatts, giving a C.C.I.R. rating of well over 200 kilowatts.

$$(160 \times 1 + \frac{0.8^2}{2} = 211).$$

Every water-cooled valve in the transmitter, both in this stage and the intermediate amplifier, is fitted with a Thermostatic relay which operates a buzzer and a red lamp should the cooling water temperature exceed a certain predetermined limit.

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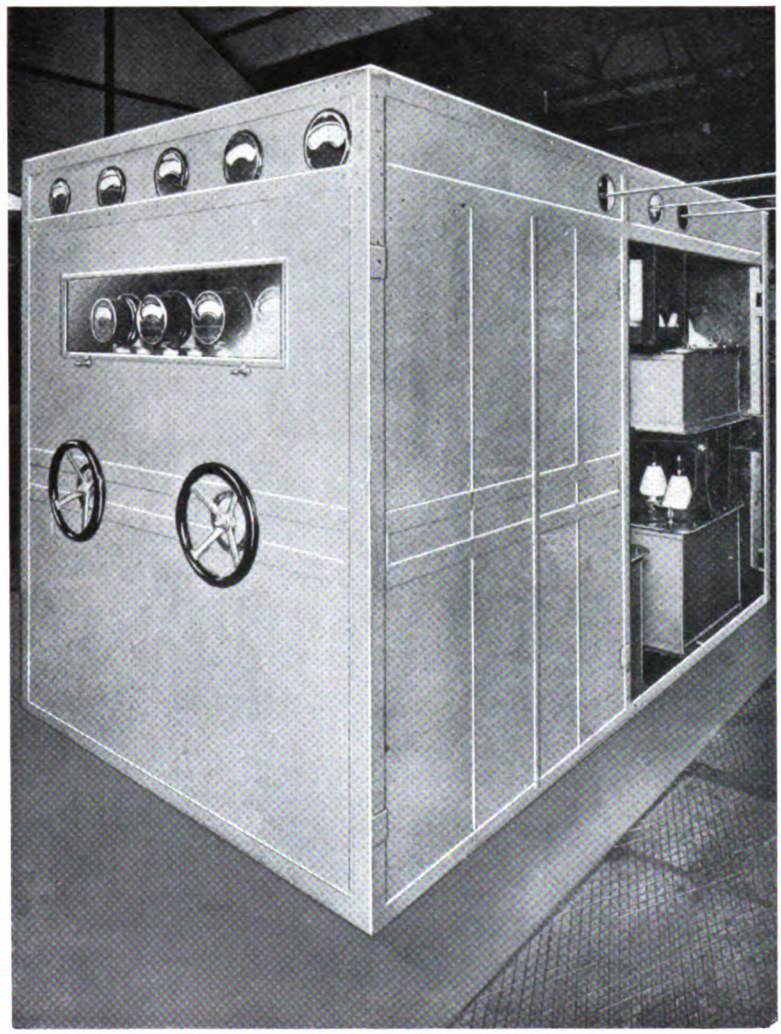
(5) The Harmonic Filter and Aerial Coupling Unit.

On account of the high power of the station, and particularly bearing in mind the working wave length, great care has been taken to reduce harmonic radiation to the lowest possible limits. One of the principal factors in securing the necessary attenua-



Main Oscillatory Circuit.

tion is a low-pass filter, which is inserted between the output circuit of the transmitter and the aerial feeder. The filter comprises three sections, and is, of course, com-

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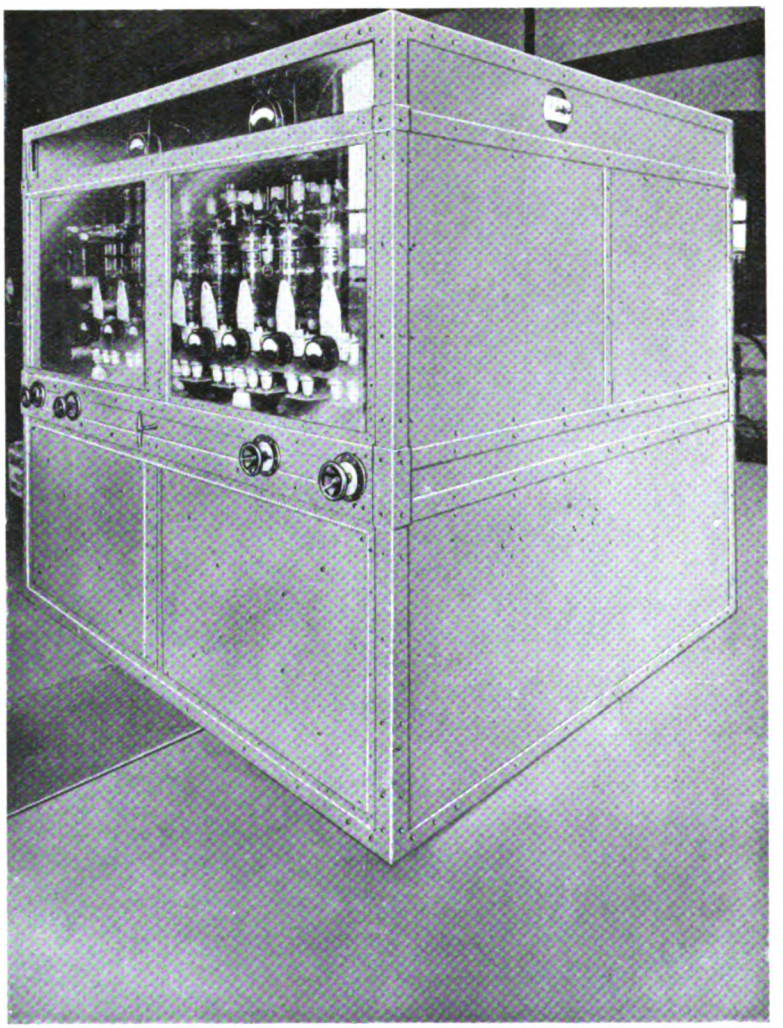
pletely enclosed in a metal screening case. It is designed to work into a terminal impedance of 500 ohms, and the twin wire feeder which conveys the power to the remote aerial is consequently designed to have a surge impedance of the same value.



Intermediate Amplifier.

The feeder terminates across a condenser, forming a capacity coupling to a tuned closed circuit, to which in turn is coupled the aerial. The aerial will be supported by two towers of 200 m in height, and aerial heating arrangements will be provided for melting ice or snow from the wires.

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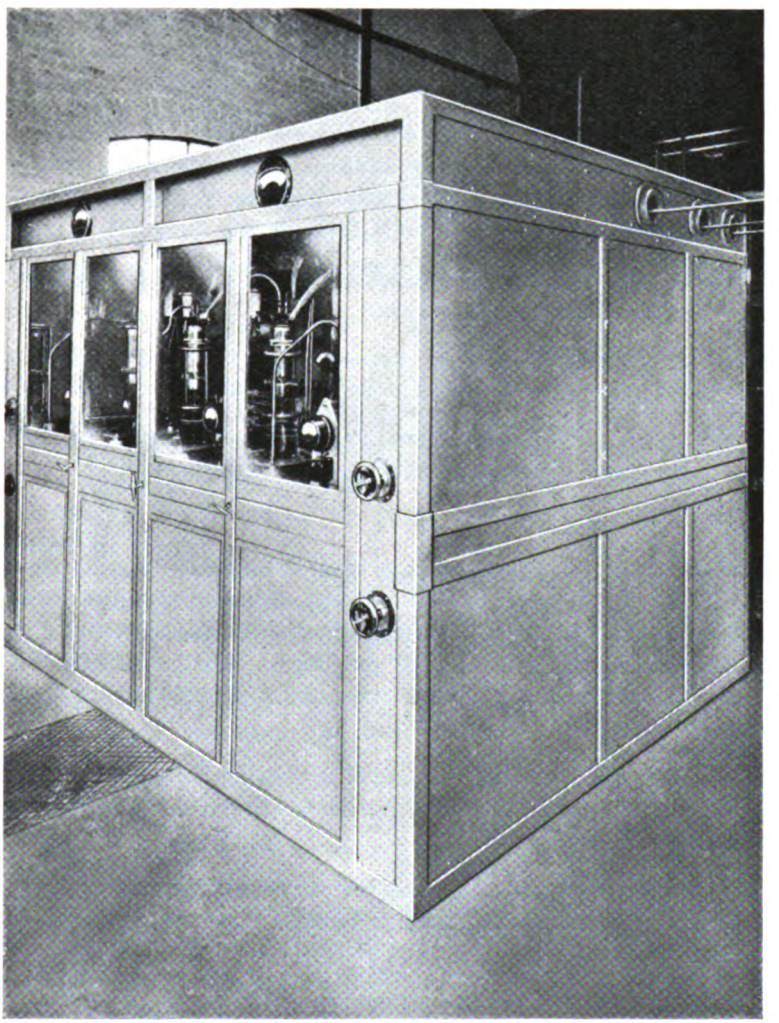
(6) The Rectifier and other Power Plant.

Power for operating the station will be taken from an outside three-phase supply. The main high tension direct current required for the intermediate and power ampli-



One of the Last Stage Power Amplifiers.

fier valves is to be provided by Brown-Boveri mercury-steel arc rectifiers. Two of these are being installed, each rated at 500 kilowatts at various voltages between 10,000 and 15,000. The first of these high voltage arcs to be employed for radio work

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was erected by the British Brown-Boveri Company in the Marconi Research Laboratories at Chelmsford, the particular unit being rated for 400 kw. at 12,000 volts, and has proved very satisfactory in service. The high efficiency, ruggedness and negligible maintenance costs, enable this type of rectifier to compare very favourably with any alternative method of generating high tension direct current. The Warsaw arc rectifiers have actually been tested up to 800 kilowatts at 28,000 volts, so there is obviously a large factor of safety in hand.

The rectifier is arranged to produce hexaphase currents, and the ripple is filtered by the usual arrangement of iron core chokes and condensers. The greater part of the capacity is grouped at the end of the smoothing circuit, and this will prevent any undue attenuation of the low note register during modulation.

The various valve filaments will be heated by a direct current dynamo capable of delivering 2,200 amperes at 20 to 40 volts.

A separate rectifying plant using glass envelope thermionic valves will provide the D.C. supply at 3,000 volts, required for the low power stages of the set.

Grid bias voltages are taken from D.C. dynamos varying from 50 to about 2,000 volts, as necessary for the different types of valves employed.

General.

Rather elaborate arrangements have been incorporated in the transmitter for ensuring the safety of the staff, and the valves. The various units of the set are all fitted with doors which cannot be opened without automatically cutting off the power and manually earthing all high voltage " bus-bars." The power switch is also interlocked with safety relay operated by the filament and grid bias voltages and the water flow indicator.

A control unit, on which are grouped voltage regulating apparatus and important indicating instruments, enables the transmitter to be operated and kept under observation from a central point.

A very complete range of measuring instruments is attached to each unit of the set so that the adjustment and operation of each stage can be correctly made and instantaneously checked.

The full power tests of the set, which were carried out at the Marconi Works, Chelmsford, have been extremely satisfactory.

The CAT.10 valves have worked with great ease and stability, and have shown not the slightest indication of internal discharges.

W. T. DITCHAM.

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WIRELESS DIRECTION FINDING AS AN AID TO AERIAL NAVIGATION

The following description of directional transmission and reception systems as applied to aircraft, indicates that each of the available systems possesses certain advantages and also certain disadvantages. There is no one system which can be said to be the "best," as the most satisfactory system to be employed depends entirely upon the local conditions of the route which is under consideration.

It has accordingly been the aim of the author to outline the pros and cons of the various systems with a view to assisting Air Operating Companies and others to understand the problems concerned, and to enable them to select that form of directional assistance which is most suited to their particular needs.

General.

THE art of navigating any mobile craft depends essentially on being able to determine the position of that craft with relation to a fixed point or points; the position may either be obtained in the form of a bearing on, and a distance from, any known fixed point, or of simultaneous bearings from two or more fixed points, which bearings are laid off on a chart and denote, by their intersection, the position of the craft at the time.

In practice, the former method of obtaining the position of the craft is seldom employed owing to the difficulty of gauging distance in a direct line; the latter method is, therefore almost universally used, whether the mobile craft be on land, at sea, or in the air, and different means are employed for ascertaining the bearings of the fixed points. For example, light waves, sound waves, wireless waves and infra-red waves are all used for this purpose, according to their suitability to the particular conditions.

The aircraft is, without doubt, one of the most difficult craft to navigate by the traditional visual methods; for one thing it is often not large enough to carry a specialist navigator on board, all navigation having to be undertaken by the pilot himself, who is usually fully occupied with flying the aircraft, etc.; even if serious navigational work can be undertaken on board the aircraft, such work has usually to be carried out under most uncomfortable and inconvenient conditions; and lastly, those conditions of visibility which render visual methods either entirely or to a large extent useless are just those which call for the greatest amount of navigational assistance being obtained by the pilot of the aircraft, and which most jeopardise the safety of the aircraft which (except in the case of an airship) cannot like other craft, reduce its speed to a safe figure under these conditions.

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Under normal conditions of visibility, aircraft are navigated by the simplest of "visual" means, *i.e.*, by the pilot keeping continual track of the position of his aircraft by reference to landmarks on the ground which are either known to him or else verified from a map; should, however, conditions of poor visibility obtain, this method becomes useless, and the pilot is forced to fall back upon one or other of the more scientific methods of navigation. Of these, there is no doubt that the most useful and the most usually employed are those methods which are provided by wireless.

Wireless direction finding systems can be divided into two basic types, which are as follows: –

(A) Those which employ directional transmission from a fixed point and non-directional reception in the mobile craft.

(B) Those which employ non-directional transmission from a fixed point and directional reception in the mobile craft, or *vice versa*.

It is not proposed in this article to give a detailed technical description of the various systems of directional transmission and reception which are available at the present time, since the reader who is interested in this matter can refer to the numerous text books on the subject, but it is felt that a brief description of the various systems is essential for a proper understanding of the problems involved in the navigation of aircraft by wireless methods.

Directional Transmission Systems.

The systems of directional transmission which are at present available for use, are provided by the "equisignal" beacon and the "rotating" beacon transmitters; each of these comprises a fairly powerful and costly transmitter, which is obviously only suitable for ground installation.

Equisignal Beacon.

The equisignal beacon transmitter provides a number of "zones" of equal signal strength, which radiate in straight lines from the transmitting aerial system and which can be oriented in any desired direction; the presence of the "zones" is indicated to the pilot of an aircraft either by means of a characteristic signal received in the telephones of his receiver, or by means of a visual indicator installed on the dash-board of his aircraft and operated by his receiver.

By means of either indicator, the pilot is continuously notified whether he is on his correct course or not, and if not, whether he is to port or to starboard of the course. Such indication does not, in itself, give the pilot any information as to his actual position, *i.e.*, how far along the particular course he has flown; this information is supplied by what are known as "marker" beacons, which are erected at periodic intervals along each course of the route, and which comprise low-power

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non-directional transmitters, each of which transmits a characteristic signal which is received by the pilot in the form of either an aural or a visual indication. The ground-to-air range of such marker beacons is small, being of the order of 5 miles, and their purpose is simply to "mark off" each course and give the pilot an automatic indication of position as well as of his course. Arrangements can also be made whereby telephone transmission from either main or marker beacons can be temporarily provided in place of the normal beacon transmissions; by this means, information as to route, weather conditions, etc., may be broadcast to pilots flying along the route.

The results obtained with this system under conditions of daylight are very satisfactory, ranges of up to 120 miles or so having been obtained on numerous occasions, the width of the equisignal zone being of the order of 3 miles at a distance of 60 miles from the transmitter, *i.e.*, the angular width of the zone being of the order of 3°.

In this connection it is of interest to note that the use of a vertical rod antenna in the aircraft for reception purposes is claimed in certain quarters to be an essential factor in securing freedom from "night affects," *i.e.*, in permitting of the system giving as accurate results by night as by day; a considerable body of technical opinion is, however, doubtful if this is the case, since, from a purely scientific study of the matter, it would appear that "night effect" is bound to be present with this system, although the magnitude of such effect may be so small as not seriously to impair the practical efficiency of such a system at night. Prolonged and extensive tests during darkness have not at present been carried out in the country, and the results of such tests when they are made, will doubtless be of the greatest interest both to technicians and to aircraft operating companies and their pilots.

A further criticism of the use of a vertical rod antenna is that it is difficult to construct such an antenna which, while being airworthy, will not seriously detract from the performance of the aircraft. Furthermore the use of such an antenna necessitates the complete screening of the engine ignition system, on account of the small pick-up obtained and the consequent need for extremely high amplification in the receiver; this latter requirement involves additional cost and weight and maintenance difficulties, and is not welcomed, at the present time, by aircraft operating companies in this country.

The "equisignal" type of beacon is obviously only applicable where each of the routes to be followed consists of a number of straight line courses, each course being of some considerable length (for example, 50 to 100 miles), as otherwise the cost of the numerous beacon transmitters which would have to be installed to cover the route would be prohibitive; furthermore, it has the disadvantage of concentrating aircraft flying in a given area along one or more sharply defined courses, with the resultant increased risk of collision during conditions of poor visibility.

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Rotating Beacon.

The "rotating" beacon provides a means whereby transmissions are continuously revolved at a regular and pre-determined speed through space, the intensity of the transmission at any point at a given distance from the beacon depending entirely upon the bearing of the beacon from the point in question ; the intensities of the transmissions revolved comprise, per revolution, two broadly defined maxima 180° apart and two extremely sharply defined minima also at 180° from each other, the maxima and minima being 90° apart. The transmission from the beacon is continuous, except when the plane of the minima is in either the N—S or the E—W direction, in each of which cases the transmission is interrupted for the sending of a characteristic signal. The rotary beacon accordingly corresponds very closely in its functioning to a luminous beacon of the revolving type which produces two very broadly defined beams of light 180° apart and two extremely sharply defined eclipses also 180° apart, but 90° apart from the axis of the light beams, and which in addition flashes a characteristic signal when the plane of the eclipse is in either the N—S or the E—W direction.

Hence, in the case of either the luminous or the radio beacon, an observer knowing the rate of revolution of the beacon, and provided with (A) a stop watch, and (B) a means of observing both the "starting" signal and the "eclipse" or minima as it passes him, will be in a position by simple computation, to calculate the time interval between these two observations, and hence the angle through which the eclipse (or the minimum intensity, in the case of the radio beacon) has swept between the true N—S plane and the plane formed by a line joining his position to that of the beacon, *i.e.*, he will know the true bearing of the beacon from his position.

The radio beacon is usually arranged so that one complete revolution per minute is made, *i.e.*, 360° per 60 seconds or 6° per second ; furthermore, the "starting" signal and the passing of the minima is observed in the form of a varying strength of signal on the telephones of a normal receiver and, finally, a specially calibrated stop-watch is provided, in which the seconds hand "boxes the compass" in one complete revolution, *i.e.*, in one minute. An observer accordingly starts his stop-watch when he hears, say, the characteristic N—S signal, and stops it when he hears the first of the two minima—which, as stated above, are extremely sharply defined and which can, with practice, be gauged to less than one half of a second ; the position of the seconds hand then gives him a direct indication of the bearing of the beacon from him.

From the foregoing it will be seen that no extra equipment is required in the aircraft over and above the normal receiver—apart from the stop-watch—and what is more important, any number of aircraft can avail themselves simultaneously of the direction finding service ; furthermore, the service is not—as in the case of the

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equisignal beacon—confined to certain pre-determined straight line courses radiating from the beacon, but is available in any direction from the beacon up to the limit of range available. Unfortunately, by virtue of the fact that the radiating circuit of the transmitter is extremely inefficient, comprising a relatively small closed loop of wire (which is revolved, as explained earlier), the power of this type of beacon—and hence its cost—has, for a given range, to be greater than that of any other type of directive or non-directive ground beacon transmitter ; furthermore with this type of beacon freedom from night effects cannot be definitely guaranteed, *i.e.*, the accuracy of the system at night is liable to be of a lower order than that obtainable by day.

In practice, however, exceedingly successfuly results have been obtained, in daylight, with beacons of this type, an average accuracy of within a degree or two being possible when observations are made on the ground, and within three to five degrees when the observations are made in the air ; under certain conditions it is possible to foresee a great use for a chain of beacons of this type, especially where navigational aid is required over an area in which aircraft are not flying along a few pre-determined routes, but where the area is more or less completely covered by a network of routes.

Other Directional Transmission Systems.

In addition to the above systems of directional transmission which have definitely reached the stage in which practical use can be made of the navigational aid provided, experimental work is at present being carried out on several other forms of directional transmission. In one system, for example, a sharply-defined unidirectional " beam " (which is produced by means of a special aerial system comprising a number of vertical energised aerials having reflecting aerials—also vertical—behind them, the whole system being mounted on a rotatable frame) is continuously rotated through space at a predetermined angular speed ; distinctive Morse signals are transmitted when the " beam " is oriented in the various directions corresponding to each of the cardinal points of the compass, and ultra short wavelengths (of the order of 6 metres) are employed. When the receiver on the mobile craft is tuned to the correct wavelength, a series of three of four of these distinctive signals are heard at regular intervals of approximately two minutes : these signals occur in a definite order, which, by reference to the chart of distinctive signals transmitted indicates the orientation of the " beam " as it sweeps past the receiver, and hence the true bearing of the transmitter from the receiver. In a second system, a sharply defined unidirectional " beam " is projected in any desired (fixed) direction ; short wavelengths are employed and an indicator is provided on the aircraft to warn the pilot whether he is flying along the correct course or not. In another similar system, the " beam " can be oriented in any desired vertical as well as horizontal plane, with a view to providing assistance in landing during fog. In yet another

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system, a combination of two rotating beacons is utilised, short wavelengths being employed ; the total time per revolution of each beacon is identical (the beacons being synchronised for the purpose), but the speeds of revolution of the beacons are different, being governed in each case by a cam or similar mechanism. By so arranging the contours of the cams it is possible to arrange that the successive points of intersection of the zones of maximum intensity which are swept out by each of the beacons will trace out, in space, any desired path, which can be altered as required by altering the contours of the respective cams ; a continuous series of dashes is transmitted by one beacon and a series of dots from the other. Hence the pilot of an aircraft flying along the correct course will hear in the headphones of his wireless receiver, for each revolution of the beacons, a continuous signal formed by the "interlock" of the dots and dashes ; should, however, he be to one side of his correct course, he will hear, for each revolution of the beacons, a series of dots followed by the continuous signal, followed in turn by a series of dashes, or, if he is to the other side of his course, a series of dashes, followed by the continuous signal, followed in turn by a series of dots. It is claimed that, by careful mathematical study of the contour of the cams, it is possible so to arrange matters that the number of dashes (or of dots) heard by the pilot before the commencement of the continuous signal, will be an indication of the lateral distance by which the aircraft is off the correct course. Each of the above systems, it will be noted, employs short wavelengths ; owing to the well-known effects associated with short wave propagation, however, such as "skip," "scattering," etc. (which are phenomena inherent to propagation at these high frequencies), further experimental work on short wave directional transmission systems will be necessary before a decision as to their practical value can be given.

Directional Reception Systems.

The basic principle underlying the operation of all systems of directional reception is that the reception properties of an aerial consisting of a simple loop of wire are directive, being at a maximum in the plane containing the loop, and at a minimum at right angles to this plane ; the two maxima in the plane of the loop, which are of course 180° apart, are broadly defined, whereas the minima at right angles to this plane are extremely sharply defined. Hence, if the loop aerial be connected to a receiver, tuned to the wavelength of the transmitter whose direction it is desired to ascertain, and slowly rotated in the field produced by this transmitter, two positions of the loop will be found in which the strength of the received signal will rapidly decrease to zero and as rapidly increase again in audibility ; these two positions of the loop will, of course, be in the same plane (*i.e.*, will be 180° apart), and this plane will be at right angles to the plane joining the source of the transmitted signal and the directional receiver. From this it follows that the orientation of this latter plane can be ascertained with no small measure of accuracy, the only information which is lacking in this simple system being that the actual bearing of the transmitting

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station relative to the directional receiver is subject to an ambiguity of 180° ; in the various systems which have been developed from this simple system, devices are, in most cases, incorporated in order to overcome this ambiguity and to give the actual bearing of the transmitting station. Before describing the more important of these systems it is as well to point out that in most cases the directional receiver can either be installed on the ground (and take bearings of the aircraft transmissions), or can be installed in the aircraft (and take bearings on transmissions emanating from known points on the ground) ; there is, however, one exception to this rule, which occurs in the case of the Marconi-Adcock system, in which the aerial system necessary could only be installed on the ground, for both technical and practical reasons.

Marconi-Bellini-Tosi System.

In this system, the aerial system comprises two loops of wire rigidly supported at right angles to each other and to the horizontal ; each loop is split at the centre of its base, and a pair of leads run from there to the apparatus which is employed for taking bearings, *i.e.*, the radiogoniometer. This latter comprises a relatively small unit containing two coils of wire rigidly and accurately supported at right angles to each other (the field coils), within which coils lies a rotatable coil called the search coil ; this latter is mounted on a spindle, one end of which projects through to the outside of the case containing the field and search coils, where it is provided with a knob of convenient size for comfortable operation, and with a pointer, which, of course, rotates with and indicates the position at any moment, of the search coil. A carefully engraved scale from 0° to 360° is provided on the outside of the case, in such a manner that the orientation of the pointer can be read with great accuracy. From the search coil of the radiogoniometer two leads run to the tuning and amplifying circuits, the output of which latter is taken to a pair of telephones.

Transmissions arriving from any particular direction induce high frequency voltages and currents in each loop and hence in each field coil, their magnitude depending on the angle formed by the plane of the loop and the line joining the transmitting and receiving stations ; the result is the formation of a " resultant field " within the field coils, the plane of this field being identical with that of the incoming transmission. By rotating the search coil within this field, therefore, an operation is performed which is identical with that which takes place when a simple loop aerial is rotated in the field of a transmitter, *i.e.*, two broadly defined positions will be found where signal strength is at a maximum, and two sharply defined positions where the signal strength is at a minimum. By calibrating the radiogoniometer, *i.e.*, by taking observations on a transmitter whose bearing relative to the receiver can be accurately obtained from a map or calculated by other means, and by then altering the position of the pointer relative to the spindle of the search coil until the position indicated by the pointer on the scale tallies exactly with the bearing as so determined, the bearing of any transmitted signals can be

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obtained by the simple process of tuning the associated circuits to the correct wavelength, rotating the search coil until a position of minimum signal is found, and reading the bearing off the radiogoniometer scale. As mentioned above, the bearing so obtained is subject to an ambiguity of 180°, but, by means of a special circuit which can be switched in or out at will, the " sense " of the bearing can be obtained, *i.e.*, the true bearing differentiated from that which is incorrect by 180°.

This system is obviously applicable to either ground or aircraft use. In the former case, the aerial system usually comprises two single turn loops of triangular shape supported on a central mast some 80 ft. in height and having a base of some 100 ft. or so. Such a station, if erected at an aerodrome, can ascertain the bearing of transmissions emanating from an aircraft, and hence of the aircraft itself ; furthermore, by providing two or more such stations to cover a particular route, with a rapid means of intercommunication between them, it is possible to ascertain with great accuracy the position of an aircraft by taking simultaneous bearings on the aircraft's transmission at each station, laying off the bearings on a chart, and ascertaining the resultant position as given by the intersection of the bearings. This application of the Marconi-Bellini-Tosi method is extensively employed for civil air route work in Europe, and offers the advantages that : (A) the pilot is given an actual position without any necessity for calculations on his part ; (B) the process of obtaining a position is effected in a very short time, a minute and a half sufficing so far as British D.F. stations are concerned ; (C) the system is capable of great accuracy by day : (D) a network of such stations can serve a large area, not being confined to a few directions, as in the case of the equisignal beacon. On the other hand, there are certain disadvantages with the system, which are as follows :—(A) In order to obtain a bearing or a position, a transmission for the aircraft is necessary. In these days when air route traffic is becoming relatively dense, the wave allotted for aircraft communications is congested, and any extra transmissions on this wave should be eliminated ; of course, this could to a certain extent be overcome by utilising a different wavelength for D.F. purposes than for normal communications, but this involves the provision of two receivers (and possibly two transmitters) on the ground —one for normal communication work and the second exclusively for D.F. purposes— in place of the one which is at present employed for both purposes, and also involves a rapid and simple wave-changing device being fitted to the aircraft set. Furthermore, while the D.F. work is going on, the aircraft is out of touch with the ground for normal communication purposes. (B) Only one aircraft can be served at a time, by any given D.F. station or stations ; with dense traffic in any particular area, when conditions of visibility are bad, the delay in service which occurs is often a matter of some import.

Where the Marconi-Bellini-Tosi system is applied to aircraft, *i.e.*, where the directional receiver is installed on the aircraft, the aerial system comprises two single

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or multi-turn loops insulated from, but rigidly affixed to the structure of the aircraft, their planes being at 90° from each other ; operation of the direction finder is in all respects similar to when installed on the ground. Bearings can be taken on any known ground transmitter whose wavelength lies within the wave band of the receiver, and hence—by laying-off methods—the position of the aircraft can be calculated with great accuracy. This system has been extensively used on long distance flights oversea, as, for example, on Major Franco's transatlantic flight in 1926, and Captain Courtney's attempted transatlantic flight in 1928 ; in the latter case, the prompt rescue of the crew after the accident which forced the aircraft down in mid-ocean can be truly ascribed to the presence of a Marconi-Bellini-Tosi direction finder and an aircraft transmitter on board the aircraft.

This application of the Marconi-Bellini-Tosi system has—like all aircraft D.F. systems—numerous advantages and certain disadvantages. On the one hand, it permits of an aircraft so equipped obtaining D.F. navigational aid in any quarter of the globe where ground wireless transmitting stations exist, even where no ground D.F. facilities are available ; furthermore, bearings can be taken and D.F. navigational aid obtained without the necessity for any transmission from the aircraft and—in many cases—without any additional transmission from the ground. On the other hand, however, the operation of taking bearings and of laying them off for calculation of position, necessitate the carriage of a trained operator and/or navigator on board the aircraft, in addition to the pilot and mechanic ; furthermore, the small pick-up of the loops used for reception necessitates the use of a highly sensitive receiver, which, in the case of most types of aircraft, in turn necessitates the screening of the engine ignition system for satisfactory reception, with the consequent addition of weight and maintenance difficulties.

This disadvantage can, however, be to a great extent overcome by the use of statically-screened loops in place of the normal large-area loops ; these loops are approximately 4 ft. in diameter and are enclosed in a static screen of streamline section, with the result that they can be mounted on the exterior of the aircraft well towards the tail assembly, *i.e.*, well away from the engines, and screened leads run forward up to the receiver which is installed in the normal position. Owing to the smaller area turns of these loops as compared with the normal type, the pick-up is appreciably less, but the interference received from the ignition system is reduced to an even greater extent, with the result that the range obtainable is greater than with the normal loops and an unscreened engine, and nearly as great as if the engine ignition system had been completely screened.

One grave defect is, however, present in the Marconi-Bellini-Tosi system in common with all other systems except the Marconi-Adcock system (which will be described later) ; this is that at any time between sunset and sunrise, it may be-

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impossible to obtain satisfactory bearings owing to what is termed "night effect." At certain times while "night effect" is present, the minimum on which the bearing is taken, is so badly defined as to make it impossible to take an observation; at others the minima are sharply defined but anything up to 30° or 40° inaccurate, and at others again they are normal. The result is that no D.F. service can be guaranteed at night, which, in these days of incipient night services, is a matter of great import. Hence, the evolution of the Marconi-Adcock system is one of the greatest advances in the art of wireless direction finding that has been made for many years.

Marconi-Adcock System.

This system has been developed within the last few months, in order to provide a service having all the advantages provided by the Marconi-Bellini-Tosi system, but lacking its chief disadvantage, *i.e.*, the susceptibility to "night effect." In this it has been remarkably successful, as searching tests have shown, and it is anticipated that this system will be in extensive use in the very near future all over the world, as it is the only system at present in existence which will permit of an accurate D.F. navigational service being given at night.

"Night effect," in so far as it effects wireless direction finding systems, is due to the effect on a normal directive aerial system of vertically polarized waves, which have been reflected from the Heaviside layer and which, in combination with the non-polarised waves which have travelled along the earth's surface from the transmitting aerial, produce an effect which results in the normal directive properties of the receiving aerial system being distorted—and, in some cases rendered non-existent. These effects are unfortunately completely variable, and may vary from second to second, minute to minute, and hour to hour; hence, any D.F. system which is affected by such reflected waves is practically useless during darkness.

The principle of the Marconi-Adcock system is to provide an aerial system which is unaffected by these reflected waves, and which is only affected by the direct waves. The aerial system is suspended from four self-supporting wooden masts on lattice steel towers some 70 ft. in height, and arranged at the four corners of a square whose diagonal length is approximately 300 ft. from a cross arm at the top of each of the masts or towers is suspended a single vertical wire, which, at its base (approximately 5 ft. above the ground) is connected to a junction box from which runs Franklin feeder tube along the diagonals of the square to the building housing the radiogoniometer and amplifier, which is placed at the geometrical centre of the square formed by the four masts or towers. This feeder tube comprises two concentric copper tubes, the inner or conducting tube being insulated from the outer tube by means of annular porcelain insulators spaced at regular intervals; the feeder tube is supported at a height of some 2 ft. off the ground, and is earthed at several points. Before entering the building, each of the four tubes is taken

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underground and led up through the floor of the building direct to a special radiogoniometer which is provided with a complete metallic screen, to which each of the outer tubes is very carefully connected ; the inner tubes are connected to the radiogoniometer from which screened leads are taken to the associated tuning and amplifying circuits in the same manner as with the Marconi-Bellini-Tosi system.

In so far as the basic principle underlying this system is concerned, *i.e.*, the use of a radiogoniometer, there is no difference from the Marconi-Bellini-Tosi system, furthermore, the method of operation is identical, but as stated above, the fundamental advantage of this system is that " night effect " is eliminated and a satisfactory service can be offered when it is most required, *i.e.*, during conditions of fog or low cloud at night.

Marconi-Robinson System.

This system is a development from the simple loop method of obtaining directional reception, and is only applicable for installation on aircraft, where it forms a useful method of " homing " the aircraft on a known transmitting station. The aerial system comprises two single or multi-turn loops insulated from the structure of the aircraft but rigidly fixed thereto at right angles with one another, one loop being in the fore and aft plane, and the other in the athwartships plane of the aircraft ; the connections from these loops are taken to a tuner box containing tuning and switching arrangements, which in turn is connected to an amplifier, the output of which comprises a pair of telephones worn by the pilot. The tuner box, which is mounted in a convenient position in the pilot's cockpit, contains an automatic switching and indicating device which is driven by means of a small windmill mounted on the outside of the fuselage ; the effect of this switching device is to connect the output of the athwartships loop alternatively in phase and in opposing sense with that of the fore and aft loop which is tuned to the signal transmitted from the ground station. Assuming, therefore, that the head of the aircraft is pointing directly at this station, a signal of a certain steady strength will be heard by the pilot, such signal being entirely due to pick-up on the fore and aft loop, since the athwartships loop will be exactly at right angles to the direction of the incoming wave and so will have a zero pick-up ; hence connecting the output of the athwartships loop in alternate sense will have no effect on the signal received. Assume that the head of the aircraft is now no longer pointing towards the transmitting station ; a certain signal is received from the fore and aft loop, but as the athwartships loop is now no longer at right angles to the direction of the incoming signal, the alternate " addition " and " subtraction " of the output from this loop to that of the fore and aft loop will cause the formation of a resultant signal of greater intensity in one case than in the other. As explained above, the tuner box contains an automatic indicating device which comprises a circular disc divided into three equal segments which

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are coloured red, green and white respectively, and which are rotated behind a small "window" in the case of the box by means of the windmill drive ; should the pilot hear a series of signals of equal magnitude when the red portion of the indicating disc is exposed, then it indicates to him that he must turn to port to "head" his aircraft on the transmitting station in question ; should the equal magnitude signals be heard while the green portion of the disc is exposed, he will have to turn to starboard in order to "head" his aircraft on the transmitting station ; and should the signals be heard while the white portion is exposed, it will indicate that he is on the correct course, which need not, therefore, be altered.

The advantages of such a system are numerous ; for one thing the pilot is guided to a fixed destination by a means which is entirely automatic in action, *i.e.*, in which he has no operation to undertake ; this enables this system to be employed for aircraft in which no observer or navigator is carried, and in which the pilot is too occupied with actual pilotage to devote any of his time to the operation of wireless navigational instruments.

There are, however, certain disadvantages which are inseparable from this system ; the chief of these is that the system is definitely not free from "night effect" ; the extent to which such effect will prevent the successful operation of the system has not been ascertained, but it is thought that, in practice, the results at night will be sufficiently accurate to enable a pilot eventually to arrive at a predetermined destination.

Other disadvantages of this system are that, should a wind be blowing across the direct line joining the aircraft and its destination, the aircraft, while eventually reaching its destination, will not do so by the shortest route, *i.e.*, its path will be a curve, constant corrections to the course being necessary by the pilot ; furthermore, since the pick-up of this system (like any other which relies on the reception of signals in the air on a loop aerial) will be small and will hence necessitate the use of a high amplification receiver if practical ranges are to be obtained, reception will be more subject to interference from the engine ignition system than if reception were carried out on the normal trailing aerial ; this will, in many cases, necessitate screening the ignition system which may introduce complications owing to additional weight and maintenance difficulties.

This system, however, notwithstanding the above disadvantages, provides a method which is extremely simple and reliable by day for bringing an aircraft to a desired destination ; it has been in use for many years and has given excellent results.

Other Directional Reception Systems.

Other systems have been developed either from the simple loop reception system or from one of these described above ; these include the fuselage coil system, in which

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the fixed loops normally employed in the Marconi-Robinson system are replaced by two coils fixed at right angles to one another and mounted in the fuselage in such a manner as to be rotatable, a scale and pointer being provided to indicate the angular position of the coils at any time relative to the fore and aft line of the aircraft ; by employing a hand or automatic switching device for connecting the output from the athwartships loops alternately in phase and in opposition with that of the fore and aft loop—as is done in the case of the Marconi-Robinson system—and at the same time by rotating the coils relative to the fore and aft line of the aircraft until no change in signal strength is noted when the reversing switch is operated, it is possible to ascertain the direction of any particular station. This method has not proved very practicable since, in addition to the disadvantages specified in the case of the Marconi-Bellini-Tosi system, it involves the use of a relatively bulky coil assembly (which takes up valuable space in the aircraft), and, in addition, is liable to an ambiguity of 180°. Yet another system which has been tried out necessitates the use of a loop of wire rigidly fixed to, and insulated from, the structure of the aircraft and installed in a plane at right angles to the fore and aft line of the aircraft, and of a normal trailing aerial ; by suitably combining the pick-up from these two antennae, it is possible to provide a means of determining the bearing of a particular transmitting station, without the ambiguity of 180° which is present in the case of the Marconi-Robinson or fuselage coil methods. The required result can, however, only be obtained by turning the head of the aircraft until the indication of a correct course is obtained, *i.e.*, this system is primarily intended for " homing " purposes and gives results comparable to those provided by the Marconi-Robinson system.

Various other systems have been tried out with more or less success, but, for various reasons, have not been found to be practicable ; in general, the only systems which have entered into general use, are those which have been described above.

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MARCONI NEWS AND NOTES

SHORT WAVE BROADCASTING STATIONS.

THE reception of the programmes radiated by short-wave broadcasting stations over very great distances, under favourable conditions, has now become a commonplace, and in its modern designs for stations of this type the Marconi Company has concentrated not only on ensuring a wide range but also a high quality of reception.

Up to the present the novelty of receiving from distant stations has perhaps compensated the enthusiasts for any lack of quality, but with the erection of standard short-wave broadcasting stations intended to give a regular service to ordinary listeners in distant areas, the factor of quality assumes great importance, as in the case of ordinary medium-wave broadcasting stations.

That the new Marconi short-wave broadcasting station which has been erected near Rome for the Italian Broadcasting Company, and which was described in the Marconi Review No. 20, fulfils this requirement, is indicated by the number of reports received placing emphasis on the clarity of reproduction.

The South African Broadcasting Company state that they have received the Rome Station on 80 metres and rebroadcast its programmes with excellent results. Their report adds " The clarity of reproduction and the steadiness of the wave were of a considerably higher order than has been obtained from any previous relay of an overseas short-wave station."

Russian technicians have also informed the Marconi Company that the Rome short-wave station is very well received in Russia and is of exceptional strength and quality.

Public Telephone Service at Sea.

Another report concerning the value of Marconi wireless telephone installations comes from Holland.

The Dutch passenger steamship " Princess Juliana," of the Zeeland Steamship Company, plying between Flushing and Harwich, has been fitted with a Marconi Type X.M.C. wireless telephone set of 500 watts power modified for duplex working.

With this equipment, good communication was established as soon as the ship put to sea, with the receiving and transmitting stations of the Dutch Post Office at Noordwyk and Scheveningen Radio, and throughout each journey it is possible for the Captain and passengers of the ship to communicate by telephony with any subscriber in Holland. Several hundreds of conversations with persons all over Holland have taken place, and a large number of enthusiastic reports have been received by Radio Holland on the success of these conversations.

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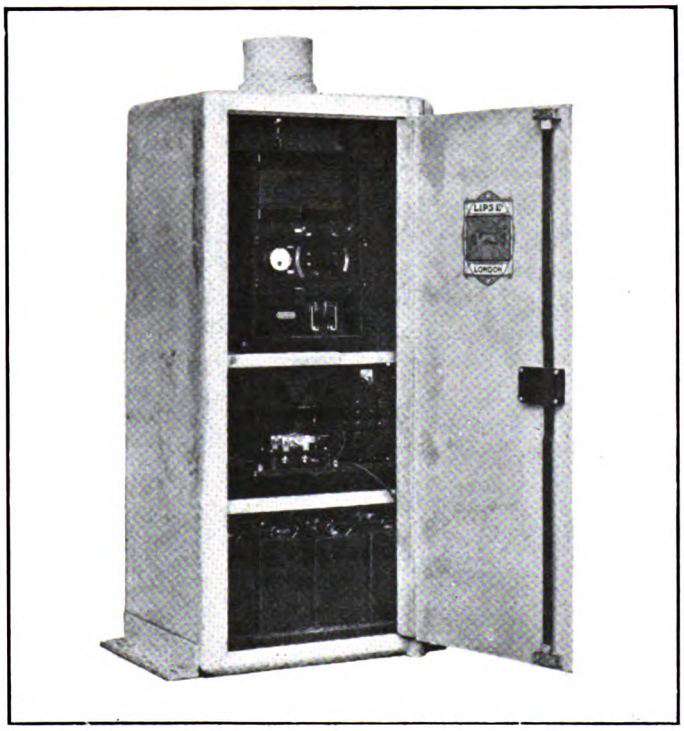

Marconi " anti-piracy " equipment installed in a safe.

All these reports emphasise the excellent quality of the service, especially the clearness of speech and the absence of background noises.

A striking demonstration of future possibilities was also given when communication was established from the ship, through the Dutch Post Office wireless telephone service, to Bandoeng, Java, in the Dutch East Indies.

Wireless Guard Against Piracy.

The danger of an attack by pirates on ships is one which has to be ever in the mind of those responsible for ships sailing in Chinese waters, as many experiences during the last few years have shown. Armed military guards are now carried on those ships most likely to be raided. The presence of this guard is, undoubtedly, in many cases a deterrent to pirates who may be concealed among the passengers, but cases have occurred where the pirates have believed they could outwit or overcome the guard, and desperate and, sometimes, successful attempts have been made to do so.

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To obtain further assistance when such an attack takes place, reliance must be placed on wireless communication, and, in order to do this, adequate protection must be forthcoming for the operator and the wireless installation. An effective and practical solution to this problem has been supplied by the Marconi Company by the development of an automatic transmitter fitted in a fireproof safe, and equipped with the necessary power supply for immediate use. This was first brought out by them in 1924. By the mere closing of a switch the wireless transmitter is set in operation, and the safe is then locked, leaving the transmitter secure from attack while it radiates automatically the ship's call sign and the request for assistance. This transmission continues uninterruptedly until either the necessary assistance arrives or until, after some hours of continuous working, the batteries lose their charge.

How Help is Summoned.

It has been found in practice that pirates only attack the coastal and river steamers, and not deep sea ships, and, as the position of these ships is known practically from hour to hour, it is unnecessary to transmit the position of the ship in any wireless message sent out when the vessel is attacked. The simple transmission of the ship's call sign and the distress call is sufficient information for the local coast stations, and a telephone call to the owners will soon determine the position of the ship. The coast station can then inform all ships within range, of the details and the estimated position, so that assistance can be rushed to the spot. As direction finders are now carried by an ever-increasing number of ships, the continuous radiation from the ship in trouble provides an excellent signal from which wireless directional bearings can be taken to facilitate the rescue work.

The great advantage of this installation is that it only requires the safe to house the wireless equipment, which consists of a standard $\frac{1}{4}$ kilowatt quenched spark transmitter fitted with an automatic key in place of the ordinary operator's hand key, and no elaborate safety devices are necessary to protect it. The operator, having received orders to call for assistance, can abandon the cabin once the safe has been locked, and join the ship's company in defending the ship, knowing that the wireless equipment needs no further attention, and will continue to operate.

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THE MARCONI REVIEW

November, 1930

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THE MARCONI REVIEW

No. 26. *November, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

SHORT WAVE RECEIVER
TYPE R.C.25

The following article describes a commercial form of Short Wave Receiver Type R.C.25, developed by the Marconi Company for use either on the Beam circuits or on Short Wave Telegraph Services using non-beam type aerials.

PRACTICALLY the first short wave receiver used at Brentwood in February, 1926, on the " via Marconi " services consisted of four stages of high frequency amplification ; owing to the use of three electrode valves, great precautions in the way of screening and neutrodyning were required, the valves were decapped and were used in push-pull, but despite this, the receiver was difficult to handle and the use of H.F. amplification in commercial receivers seemed to have fallen into disrepute.

The introduction of the screened grid valve gave hope of reviving the use of H.F. amplification provided it could be shown to be advantageous and this was one reason for the design of the R.C.25 Receiver.

Certain difficulties in the operation of a multi-way short wave receiving station were becoming apparent.

There was the question of the short wave heterodyne getting back on to the aerials. The use of reaction was essential when receiving weak signals and it was also used to sharpen up the selectivity in cases of jamming from stations on the other side of the heterodyne, but its use was limited by varying frequency of the transmitter, the presence of heavy atmospherics and the use of two receivers on one feeder precluding its use altogether.

With the increasing crowding of the short wave band, jamming from strong stations the other side of the first heterodyne was becoming serious, and of course one had no redress against such a station.

Here then, the use of H.F. amplification and consequent selectivity offered advantages if it could be done.

Another consideration was the production of a cheaper form of receiver suitable for telegraph circuits of secondary importance using non-beam type aerials.

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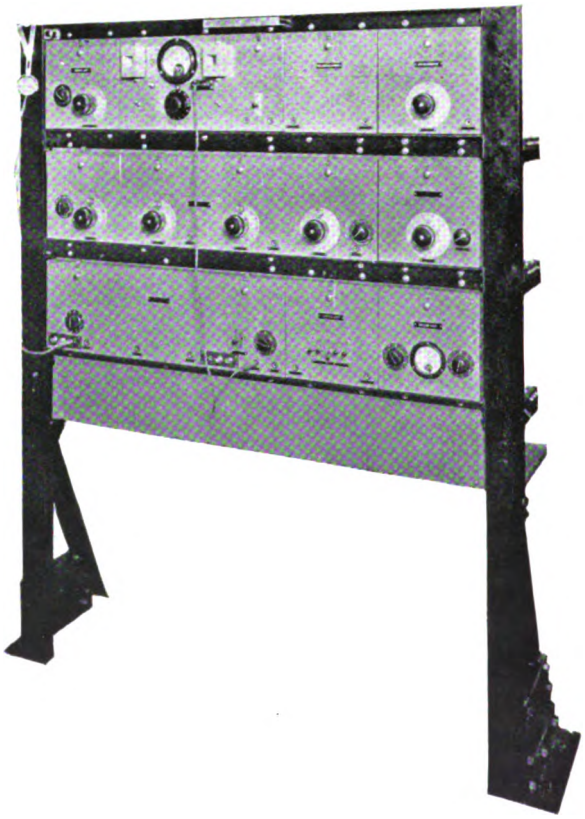
When it is considered that even on secondary circuits recording of the signal is necessary, such a disposition seems paradoxical and it was rather by improving the efficiency per stage than by lowering the effective results that any cheapening could be obtained.

While some non-Beam type aerials still had concentric tube feeders, another common feeder was of the open 2-wire type, and provision had to be made to correctly terminate either type.



Front View, Receiver Type R.C.25.

The design of suitable coils or transformers for amplification at frequencies in the short wave band presented some difficulty ; to cover the whole wave band from 14 to 100 metres necessitated plug-in coils, and the risk of limiting on heavy signals or static ruled out capacity-resistance coupling, so that plug-in transformers were required. This in turn meant the use of solid formers because self-supporting

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transformers were not feasible. In a transformer of this type the loss of magnification of the coil is largely accounted for by the capacity between the primary and secondary and to keep this down the primary must be wound with fine wire. The construction adopted differed very little from that used in the H.F. receiver referred to at the beginning of this article. The formers are 3 in. ebonite tube, the primary winding of No. 40 D.S.C. copper wire is wound in the bottom of " V " slots, and the secondaries of No. 14 bare copper are wound on the top of the slots.

Back View, Receiver Type R.C.25.

For the sake of cheapness it was decided to mount the receiver in tinned plate boxes, and this led to the adoption of astatically wound coils, there being a gain in magnification despite the extra number of turns required.

The receiver itself is a double heterodyne receiver, with amplification at three different frequencies including the fundamental, a high frequency amplifier, an intermediate frequency amplifier and a low frequency band filter amplifier, together with suitable aerial terminating and signal recording equipment.

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Screened grid valves, with high amplification factor, are used for the H.F. and intermediate magnifying stages, and thus sufficient amplification is obtained without the complication of neutrodyning or balancing to prevent feed-back effects.

For modern commercial working, a band filter width of 2,500 cycles gives the best compromise between selectivity and necessary latitude to cover varying frequency of short wave transmitters, and to allow the optimum reception of I.C.W. transmission (*cf.* Wells, THE MARCONI REVIEW, No. 22). Such a band width is obtainable with simple circuits at a frequency of about 20,000 cycles and the signal is therefore, heterodyned to this frequency.

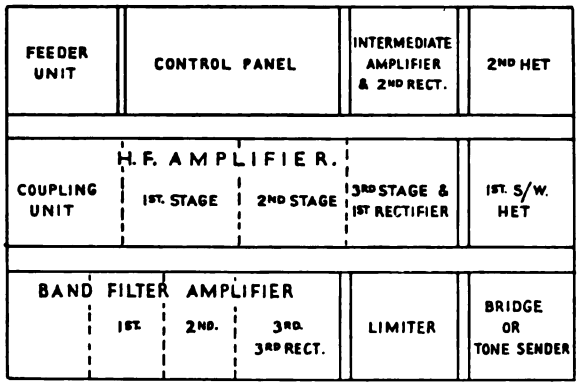

FIG. 1.

Unless, however, the circuits preceding this filter have a selectivity narrower than 40,000 cycles, twice the beat frequency, serious interference occurs from stations the same number of cycles away, on the other side of the heterodyne, as the wanted station. Such selectivity is not obtainable on short wavelengths without using such low-damped circuits that stability and the possible speed of signalling are sacrificed.

Consequently, resort has to be made to an additional heterodyne of frequency comparable to the selectivity obtainable. At 15 metres this is about 150,000 cycles in the high frequency amplifier and by heterodyning to an intermediate frequency of this value (2,000 metres) interference from the other side of the heterodyne is effectively eliminated.

The amplification obtained in the H.F. and band filter amplifiers is sufficient for all wavelengths down to about 20 metres ; below this, that of the H.F. amplifier falls off (it is between 2.5 and 3 voltage magnification per stage at 15 metres) and an additional stage of amplification at the intermediate frequency is then useful. By

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using a screened grid valve in this stage also the magnification of the single stage is about 35 to 40 with perfect stability.

Construction.

The receiver is made up in unit form and each distinct unit is contained in a metal box. A lay out of the receiver is shown in Fig. 1.

These boxes are mounted in a rack in such a way that any unit is easily removable separately without disconnecting any others; also, the arrangement allows of the rack being extended in either direction for the fitting of more than one receiver and the layout of any one receiver is flexible to suit varying requirements of space; for instance, the receiver can be arranged in one, two, three or four rows merely by use of a suitable iron rack and with no alterations to the unit boxes.

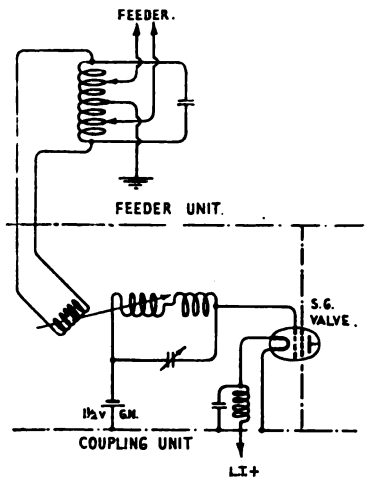

FIG. 2.

The boxes have hinged doors on the front face for easy inspection of valves and, where necessary, changing coils; the backs of the boxes are removable without interfering in any way with either the internal or external wiring or controls and this makes the examination of the whole of the equipment and wiring a very simple matter.

The buss-bars are run on the under side of the boxes and, by a simple fitting, any box can be disconnected and removed from the rack without disturbing the remainder.

Description of Units.

There are nine units as follows:—

Feeder Terminating and Tuning Unit.
High Frequency Amplifier.
First (Short Wave) Heterodyne.
Intermediate Amplifier.
Second Heterodyne.
Low Frequency (20,000 cycles) Band Filter Amplifier.
Limiter.
Bridge.
Control Panel.

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Feeder Terminating and Tuning Unit.—This unit is shown in Fig. 2 and contains an astatic inductance, tuned by a variable condenser, on which two tapping points are provided. The inductance is turned by a control and the tapping points move symmetrically over the two halves of the astatic coil, the centre of which can be earthed. This allows the correct termination of either a 2-wire or a Marconi-Franklin concentric tube feeder.

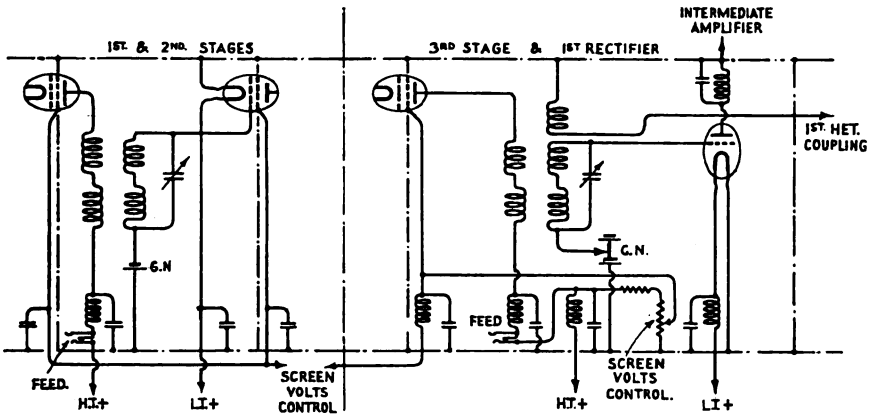

FIG. 2.

The coupling coil leads are connected across the tuned circuit and are taken out through a screening tube.

H.F. Amplifier (Fig. 3).—Consists of four screened sections :—

1. Coupling Unit.—Plug-in coupling coil variably coupled to a plug-in astatic grid coil tuned by a variable condenser ; 1½ volt grid negative battery for first H.F. valve ; H.F. choke and by-pass condenser being fitted in the L.T. positive lead which passes through the screening as pick-up on this lead would be magnified by the whole H.F. amplifier.

2 and 3. Plug-in Astatic H.F. Transformer coupling the H.F. Valves, the Secondary tuned by a Variable Condenser. The primary winding is of thin wire wound in slots beneath the secondary which is of thick bare copper wire. By-pass condensers are fitted on the H.T. and screen volts leads passing through the screening to the buss-bars.

4. Tuned H.F. Transformer, as above, across which is connected the first Rectifier Valve an H.L.610. Coupling coil from first heterodyne, fixed coupled to the H.F. transformer ; rectifier grid

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negative battery; potentiometer for adjusting the screen volts on the 3 H.F. and 1 H.F. amplifier valves, approximately calibrated 0 to 90 volts. H.F. chokes and by-pass condensers in all leads passing through the screening are essential to ensure stability of the H.F. amplifier.

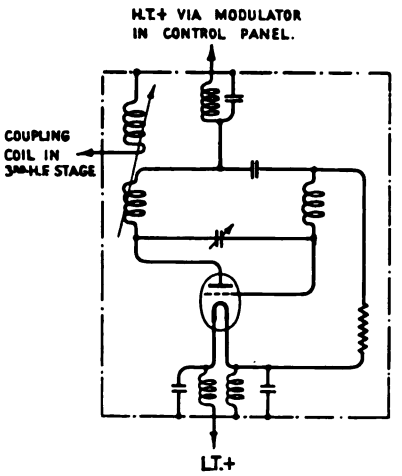

FIG. 4.

The screened grid valves, Type S.625, are carried in tubes in the screening partitions.

The voltage magnification per stage of the amplifier is about 12 to 14 at 34 meters and 2·5 to 3 at 15 meters.

The ranges of the two sets of coils which cover the normal commercial wave band are 14 to 35 meters and 21 to 52 meters. A third set is required to extend the range to 100 meters.

First (Short Wave) Heterodyne (Fig. 4).—Is a short wave oscillator with a D.E.5 valve and has been found to be very stable and free from dead spots over a wide wavelength range with given coils; only one set of coils is needed to cover the 14 to 52 meters band and a second set extends the range to 100 meters.

Only one coupling coil is required and, although the coupling is variable, is rarely adjusted in practice except when changing H.F. transformers and no adjusting means is brought through the screening.

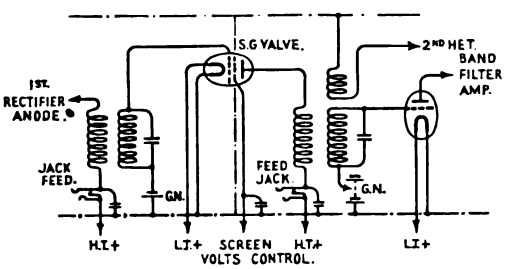

FIG. 5.

H.F. chokes and by-pass condensers are fitted in all leads passing outside the screening.

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The vernier control on the main tuning condenser is sufficiently fine for ordinary purposes but a very fine adjustment is provided by a small earthed vane rotatable into the field of the grid coil.

The H.T. feed for the oscillator is taken direct from the control unit where it can be modulated by a note oscillator.

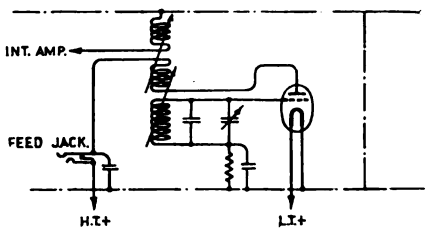

FIG. 6.

Intermediate Amplifier (Fig. 5).—Has two screened compartments.

1. A transformer, the primary being joined via a screening tube, in the anode of the first rectifier and the secondary, tuned by a small variable condenser to about 2,300 metres, is across the grid filament of a screened grid valve mounted in a tube in the partition ; 1½ volt grid negative battery.

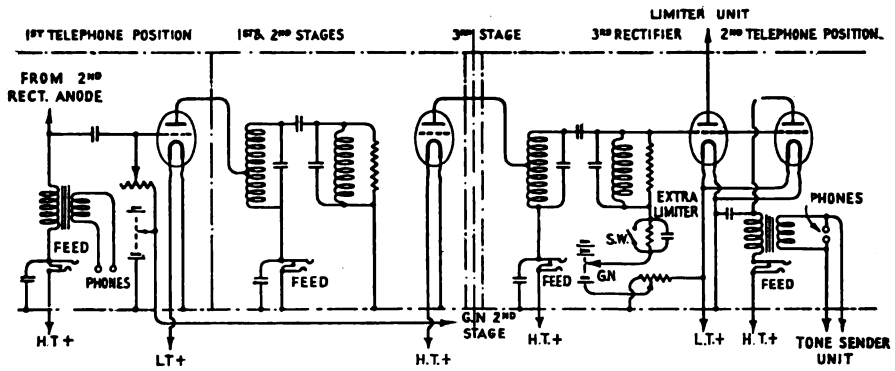

FIG. 7.

2. A transformer coupling the screened grid valve to the grid of the second rectifier, a H.L.610, the secondary also tuned by a small variable condenser ; a fixed coupling coil from the second heterodyne is wound on the same former as the transformer ; rectifier grid negative battery.

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The tuned circuits are normally fixed at about 2,300 metres but some latitude is allowed by the small variable condensers so that the intermediate frequencies of receivers in the same station may differ slightly or may be altered to avoid interference with 2,300 metre receivers operating in the same station. The controls of these condensers are not normally required and are not, therefore, brought out on the front of the unit.

Second Heterodyne (Fig. 6).—Comprises a H.L.610 valve, a 3-coil holder with standard plug-in coils. Grid, 250 turns tuned by a fixed condenser of ·0003 mfd. in parallel with a variable condenser of ·0002 max.; anode, 75 turns and coupling, 25 turns the latter being joined in series with the fixed coupling coil in the intermediate amplifier.

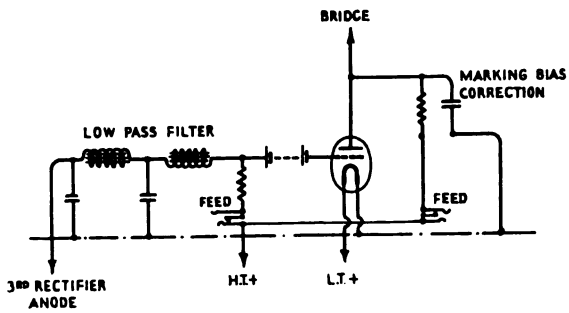

FIG. 8.

The anode and coupling coils rarely require adjustment, so their controls are not brought out on the front of the unit.

The variable condenser has two positions indicated on its dial: (1) for tuning to an audio beat note when using the first telephone position and searching on the H.F. amplifier and (2) for tuning to a beat frequency suitable for normal operation through the band filter. These positions can be varied to suit changes that may be required in the tuning of the intermediate amplifier.

Band Filter Amplifier (Fig. 7).—Contains four screened sections :—

1. First telephone transformer, coupling condenser and grid control resistance; the second rectifier (in previous unit) is choke condenser coupled to the grid of the first screened grid valve in this unit and the telephone transformer primary acts as the choke; 9 volt grid negative battery.

2 and 3. Two fixed inductances tuned to 20,000 cycles by fixed condensers, the two tuned circuits being coupled together by fixed condensers and forming a band filter. The anode resistance of the valve is across part of the input and a fixed resistance of 100,000 ohms is across the output to which is connected the grid of the succeeding valve. By-pass condensers are fitted on the H.T. and grid negative leads.

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4. A third band filter circuit as in 2 and 3, across the output of which are connected two rectifiers, H.L.610. The anode of one rectifier (the third rectifier of the set) is joined to the limiter unit ; the other rectifier has the second telephone transformer in its anode circuit At this telephone position only modulation of the signal, either inherent or introduced with the first heterodyne, can be heard. Potentiometer for controlling the grid negative volts of the third rectifying valves in this unit ; rectifiers grid negative battery ; extra limiter and switch.

The extra limiter which can be inserted by a switch consists of a 2 mfds. condenser shunted by a 30,000 ohms resistance joined in the grid negative lead of the rectifiers. It is useful under certain conditions of jamming and echo where the ratio of wanted to unwanted signal is small. It automatically adjusts the negative on the rectifier grids so that only the stronger of the two signals operates the bridge ; the condenser discharging, holds the rectifiers negative during a space and in the ordinary way its value is suitable for hand-speed signalling though this depends of course on the ratio on the two signals.

The extra limiter cannot be used during periods of deep sudden fades as it causes drop-outs which would not otherwise occur.

Limiter (Fig. 8).—Contains :—

The anode circuit of the third rectifier consisting of the anode resistance and a low-pass filter for removing modulation from the D.C. signal. The modulation is (A) the band filter frequency of 20,000 cycles ; (B) and modulation present in the original transmission and (C) that introduced by the note oscillator into the first heterodyne.

The grid of the limiter is coupled to the third rectifier anode by a grid battery of 120 volts.

A normal signal is that which just cuts off the limiter anode current by throwing its grid negative ; any further signal increase has no effect on this condition and, provided the time constant of the limiter grid circuit, including the anode circuit of the rectifier, is negligibly small compared with the period of signalling frequency, the grid of the limiter returns instantaneously to zero potential on the cessation of the signal ; hence there is no effect on the signalling bias.

Marking bias correction is applied in the anode circuit of the limiter ; it consists of 5 condensers, ·001, ·002, ·004, ·008, and ·016 mfd., which can be switched across the 0·5 megohm anode resistance.

Marking bias is a propagation effect, independent of the transmitter, the bias of which is assumed correct, or the receiver, in which a spurious component of the

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signal tends to fill in the spaces between signals. Provided that at any speed, at least some space is left between signals it can be increased sufficiently to give good legible signals.

On reception of a signal the limiter cuts off, but the condenser, charging through the 0·5 megohm resistance, slows down the rise of volts on the anode. On cessation of the signal the D.C. resistance of the anode of the limiter drops to a value negligibly small compared with 0·5 megohm, the condenser discharges rapidly and the voltage on the anode drops practically instantaneously.

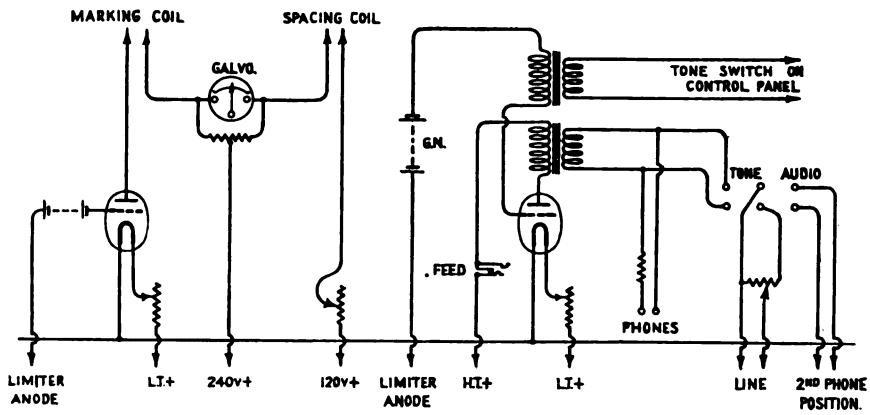

FIG. 9.

In the signal passed on to the bridge, therefore, the front of every mark is clipped while the end is unaffected resulting in a reduction of marking bias. Any value of condenser from 0 to ·031 mfd. can be obtained in steps of ·001 mfd.

This corrector is also quite useful in cleaning up clicks when atmospheric conditions are bad. If the signal is itself unbiassed the resulting spacing bias is unimportant compared with the advantage of reducing the clicks.

Bridge (Fig. 9).—This unit is supplied in two forms :—

1. For operating a relay or recorder.
2. For sending out a tone signal over a telephone line.

In (1) the grid of a marking valve, L.S.5 or P.625, with one coil of the relay or recorder in its anode circuit, is coupled by a 120 volt grid battery to the anode of the limiter valve, a steady current through the other coil provides the spacing effect when the marking valve is cut off, it is adjustable by a resistance and a centre zero galvanometer indicates balance.

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An H.T. voltage of 240 is required for this bridge unit only when using L.S.5 valve ; for medium speeds, however, satisfactory operation of the relay can be obtained with only 120 volts when using P.625 valve.

In (2) the grid of the line valve is joined through the secondary of a transformer and a 120 volt grid battery to the anode of the limiter valve. The primary of this transformer is joined through a switch to the tone oscillator in the control panel. An output transformer in the anode circuit of the line valve connects via a volume control potentiometer to the telephone line ; a telephone position is provided across the output of this transformer.

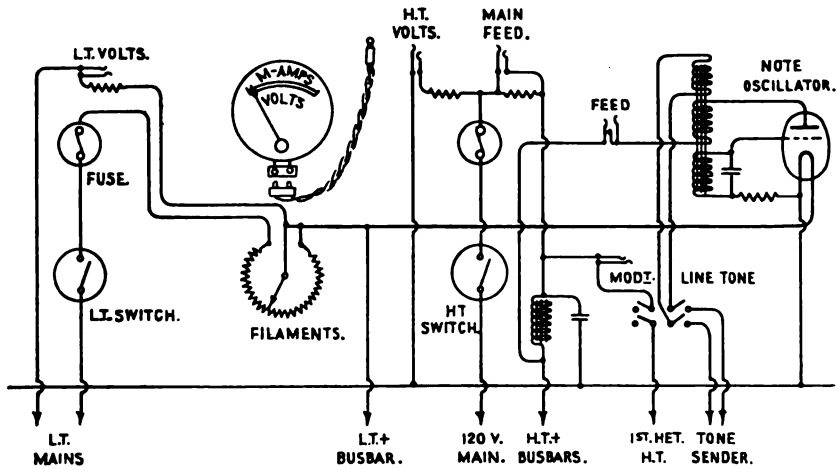

FIG. 10.

A switch enables either this output or that from the second telephone position (band filter amplifier—4) to be joined to line. The latter is used when, due to fading or conditions, there is insufficient signal to operate the bridge satisfactorily.

120 volts H.T. is used on the valve.

Control Panel (Fig. 10).—Contains :—

Note oscillator.
H.T. and L.T. switches and fuses.
Filament resistance.
Main feed choke and condenser.
Meter, resistors and shunt.

By plugging the meter into appropriate jacks, the H.T. volts, filament volts and the main feed can be read on their corresponding scales. Jacks are also provided

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on all units into which the meter can be plugged to read the individual feed of all valves in the set except the marking valve in bridge (1) which has its own meter.

The note oscillator is of fixed frequency ; by means of a switch the output can be arranged to modulate the first (short wave) heterodyne or to supply a tone to the bridge (2) or both simultaneously.

General.

Control of amplification of the receiver is affected by (1) screen volts on the H.F. and I.F. amplifiers ; (2) grid control resistance on the first valve of the band filter.

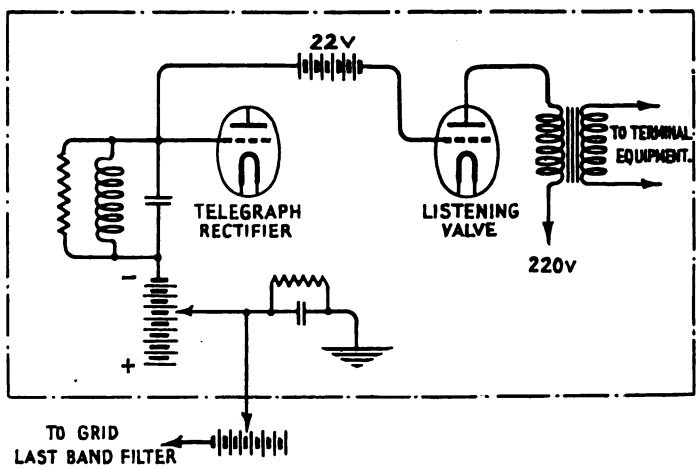

FIG. 11.

In special cases, where the maximum efficiency, normal to commercial receivers, is not required, simplified receivers can be made up of standard units. For instance, highly effective aural reception, using an ordinary aerial wire without feeder can be obtained while dispensing with the following units :—Feeder, intermediate, amplifier, second heterodyne, limiter and bridge, *i.e.*, 25 per cent. of the box capacity of the full receiver.

Telephony.

Although the frequency width of the band filter amplifier is only 2,500 cycles and somewhat narrow for telephony, quite good commercial speech is obtainable. Only minor circuit modifications are necessary to meet the requirement of maintaining a constant level of speech and with the arrangement to be described, the variation of signal strength is of the order of plus or minus 2 decibels.

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The results depend on the use of the extra limiter previously described for use with telegraph under certain conditions of small signal margin ; it is in fact a means of automatic adjustment of grid bias. In the present case it is used to adjust not only the potential of the final rectifier grid, but also the grid setting of the values in the final amplifier.

As in all forms of limiting, the method only works for reasonably strong signals. For comparatively small changes of signal strength, the automatic adjustment of the final rectifier grid potential is sufficient to maintain a good level. For greater signal strengths the slide-back effect comes into action on the grids of the amplifier valves and reduces the amplification of that stage ; the correct initial adjustment of the standing bias on the amplifier valves is of course important, so that the slide-back effect comes into action as soon as the signal passes a predetermined level. However, it is not critical.

Fig. 11 shows the connections required, a lead is taken from the top end of the condenser-resistance combination via a grid negative battery to the normal grid negative connections of the band filter amplifier valves.

The grid current control is obtained from the final rectifier normally used in telegraphy and the second telephone position valve is changed for one of lower M value and provided with additional grid negative.

This is done to avoid saturation of this rectifier which is used for obtaining the speech modulation for the output. The normal telegraph limiter and bridge units are not in use for telephony.

This arrangement was used very successfully for operating the loudspeakers at the Somerton Beam Receiving Station on the occasion of the visit of the Empire Press Conference delegates in July ; reception was from the Yacht (*cf.* THE MARCONI REVIEW, No. 22.).

J. A. SMALE.

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ULTRA SHORT WAVE EQUIPMENT FOR TANKS AND ARMOURED CARS

TYPE S.B.1A

Wireless communication between modern high power tanks moving across country at full speed does not, at first sight, appear to be a very encouraging proposition to the radio engineer.

The S.B.1A equipments recently installed in 7-ton vehicles of this class manufactured by Messrs. Vickers Armstrongs, Ltd., are the result of very successful endeavours to solve the many problems involved.

THE controlling factors in the design of the S.B.1A ultra short wave tank equipments described below have been (1) robustness to meet the severe conditions of vibration and mechanical shock; (2) compactness conforming to the limited space available in the vehicle; (3) simplicity of control for operation by unskilled personnel under conditions of severe physical stress and possibly nervous tension; and (4) the mechanical limitations placed by the nature of the service upon the construction of an aerial system.

The range required for intercommunication between similarly equipped vehicles is not extensive—1 to 2 miles as a maximum when on the move. Too great a range might in fact under service conditions be a definite disadvantage.

The problem of providing an aerial having sufficient radiation was an interesting one, inasmuch as the aerial for such service must also be inconspicuous, present as small a chance of damage under fire as possible, withstand the violent pitching and rolling of the vehicle when travelling over rough ground without collapsing, and yet be sufficiently flexible and resilient to brush under low obstructions such as branches of trees without damage to itself.

To some extent the wavelength to be employed was governed by these considerations and the use of a half wave aerial and a wavelength of 7 to 8 metres was decided upon. The remaining conditions were successfully fulfilled by the employment of a self-supporting vertical aerial constructed of jointed sections of special steel tubing of small diameter, and approximately 12 feet long. The tubing was heavily copper-plated to provide high conductivity. This aerial is supported at the base by a robust insulating bush in the roof of the tank. So resilient is the material employed that it is possible to drive the tank under an obstruction giving only 18 inches clearance above the aerial base without the slightest permanent distortion of the aerial occurring. Fig. 1 shows a general view of the tank with aerial in position.

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Fig. 2 shows the instrument box and the auxiliary units in position in the tank. The instrument box is constructed of teak and metal lined. The receiver components are contained in the uppermost compartment and normally the receiver panel is covered by a metal screening lid which is removed in the photograph to

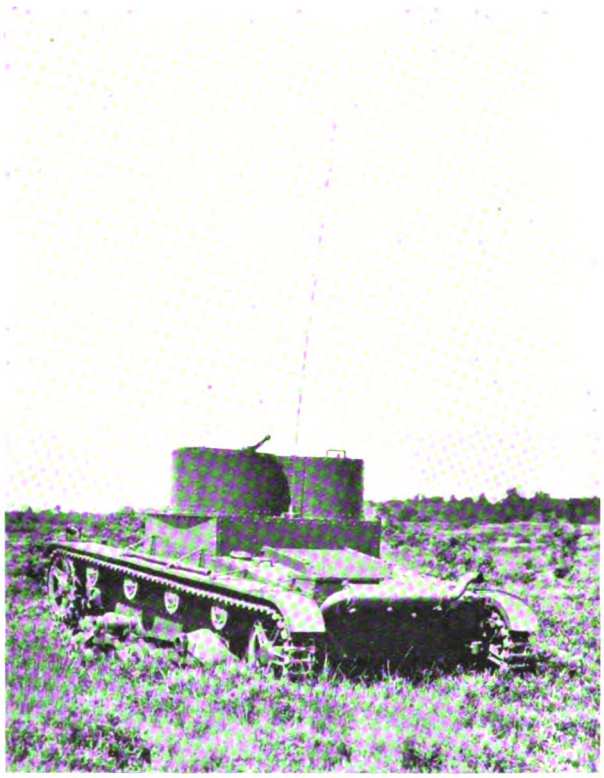

FIG. 1.

show the panel. A teak front cover completely protects the whole of the apparatus when not in use. The set is insulated from vibration by sponge-rubber, which lines the walls of the recess in which the instrument box is housed.

The intercommunication unit allows of telephonic communication between the two members of the crew provided with head sets, without their speech being transmitted. Alternatively either of them can transmit speech and both hear the received signals.

Power for the transmitter is derived from a 12-volt accumulator which may be the lighting or other accumulator in the equipment of the vehicle. High tension

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current is generated by a small rotary transformer driven by this accumulator, from which latter current is also taken for the transmitter and receiver valve filaments.

The H.T. supply for the receiver is derived from a dry battery.

The various units composing the equipment are inter-connected by armoured flexible leads provided with non-interchangeable plugs and sockets.

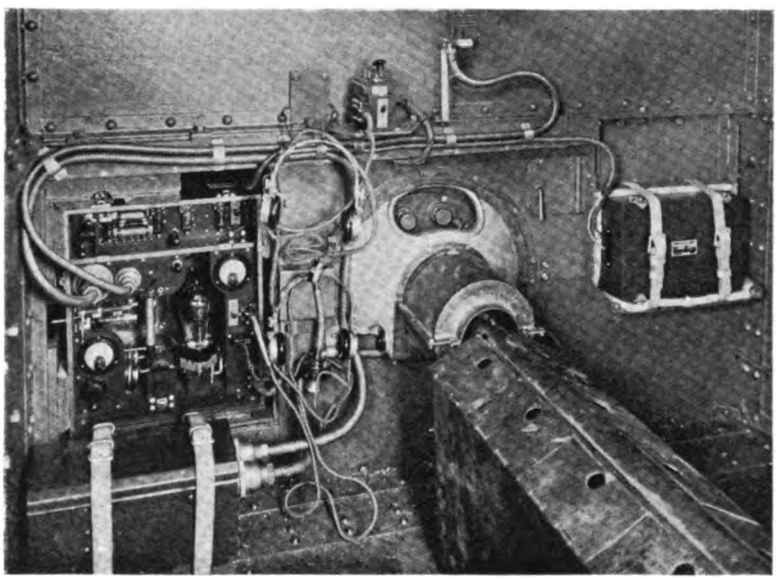

FIG. 2.

The transmitter provides for telephony and " tonic train " telegraphy. The half wave aerial feeder circuit is variably coupled to a close oscillatory circuit containing two self-oscillating valves (Type D.E.T.1) connected in " push-pull."

The frequency of the oscillations is controlled by the variable capacity connected across the grid circuit inductances.

Modulation is effected by the choke control method, two control valves (Type L.S.5B) being employed in parallel. For " tonic train " transmission, an interrupter disc mounted on the shaft of the rotary converter and a Morse key in series with it, are connected in the primary circuit of the microphone transformer in lieu of the microphone. By this means the current in the transformer primary when the key is closed is interrupted at audio frequency and these interruptions impressed on the grids of the modulators.

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The receiver employs the " super-regenerative " system wherein a high degree of amplification is obtained, with stability.

The grid of a self-oscillating detector valve (Type D.E.Q.) is variably coupled to the aerial feeder circuit by a single turn coil. Its oscillations are intermittently quenched at supersonic frequency by those of the oscillator valve (Type D.E.V.) during one half of their cycle, by means of a variable coupling between the detector and the oscillator anode inductances.

The detector is followed by two transformer coupled stages of low frequency magnification employing D.E.V. Type valves, the output from which is passed through the primary of a step-down telephone transformer, low resistance head-phones being employed.

The last stage of L.F. magnification may be switched out of circuit at will, and in order to maintain constant load conditions on the accumulator a resistance equivalent to the filament of the valve is put in circuit automatically by the switch, thus leaving the filament temperatures of the other valves unchanged.

When the receiver has been once adjusted correctly, the only controls the operator may be called upon to handle are the tuning condenser and the second L.F. amplifier switch referred to above.

The receiver valve filaments remain heated during transmission as well as reception, allowing use to be made of the L.F. magnifier stages for the amplification of inter-communication speech by means of a third winding in the first inter-valve transformer which is connected in the microphone circuit for inter-communication.

The high degree of amplification provided by this receiver is necessitated by the fact that when the tank is on the move the unprotected ear is quite unable to distinguish words shouted a few inches away, so deafening is the noise.

For this reason also, the earphones are fitted with special sound-resisting sponge-rubber pads, fitting close to the head and supported by adjustable webbing " harness," the ordinary type of anti-noise helmet as used by air operators being ruled out on account of the high temperatures experienced.

Laryngaphones are employed for telephony to avoid as far as possible the transmission of extraneous noises.

The effective range of the equipments is naturally affected to a considerable extent by the type of intervening country and particularly by the immediate surroundings of the transmitting aerial.

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The following figures are the average results of extensive range trials for two-way communication between similarly equipped tanks over fairly thickly wooded country.

Conditions.	Effective range.	
	Telephony	I.C.W.
Both tanks stationary	5 miles	6 miles
One tank moving	3 miles	4 miles
Both tanks moving	1½ miles	2½ miles

The photographs illustrating this article are reproduced by the kind permission of Messrs. Vickers-Armstrongs, Ltd., the manufacturers of the tanks, to whom our thanks are also due for their co-operation in carrying out the various trials in connection with the wireless installations.

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TYPE R.g.29c RECEIVER

The Type R.g.29c Receiver, described below, combines sensitivity with extreme selectivity.

Embodying arrangements for directive reception, it is particularly suitable for use on duplex telephony services under exacting conditions of frequency separation and space separation between receiver and transmitter.

It is, however, suitable for all general purpose reception demanding a high standard of performance, and where directive working is not called for the standard receiver may be fitted without its frame aerial, for use with any reasonable size of open aerial.

THE R.g.29c receiver consists of two units, photographs of which are shewn below.

They are :—

(A) The receiver.

(B) The frame aerial.

The Receiver.

The instrument employs one screen-grid Type H.F. stage, a detector capable of self-oscillation, and a L.F. stage.

Its waverange is 500/1,200 metres.

The receiver, complete but for H.T. and L.T. batteries, is contained in a metal cabinet shown in Fig. 1, divided into four compartments, and having a removable lid.

A useful mechanical feature is that all the components in each compartment are assembled as a unit, being mounted on a framework secured inside the cabinet by three screws easily removable from the front of the receiver. Each unit may be, therefore, quickly removed for inspection. No soldered connections have to be removed in this process, all connections entering the various units by flexible leads ; screws readily accessible on removing the lid of the receiver, free these leads from their anchor points on the cabinet itself.

Before proceeding to a general description of circuit arrangements, the following points may be mentioned.

In cardioid reception, it is often the practice to couple the vertical aerial to the frame aerial circuit by a valve. This arrangement is generally referred to as a "valve-heart." It possesses the advantage that a comparatively small vertical aerial may be employed, the amplification of the valve being available to magnify the vertical aerial E.M.F.'s to the value necessary to balance the frame E.M.F.

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The use of a " valve-heart " is perfectly satisfactory where cardioid diagrams are used to obtain the general direction of signals on a directional receiver, and it has been used for this purpose with considerable success on many commercial traffic systems. Where a clear minimum is required, however, it suffers from certain disadvantages.

The valve in the " valve-heart " arrangement is subject, like all valves, to amplitude distortion. This means in effect firstly that if a perfect balance is obtained between frame signals and vertical aerial signals amplified by the valve, this balance

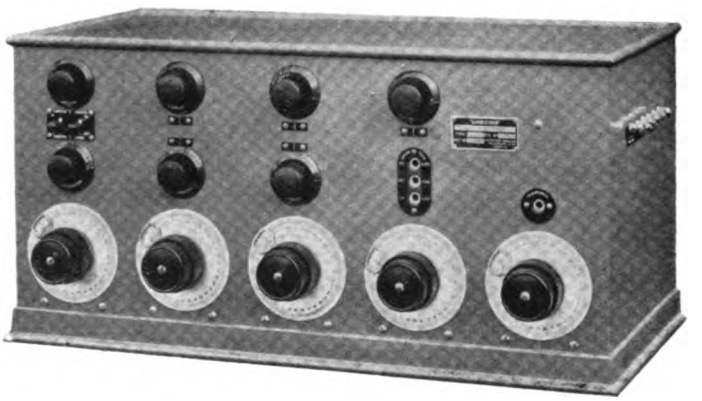

FIG. 1.

will fail with change in the signal amplitude—a state of affairs which at once precludes the use of the heart diagram for cutting out atmospheric and similar disturbances.

Secondly, the non-linearity of the heart valve gives rise to partial rectification of received E.M.F.'s. This means that the receiver as a whole may function as a super-heterodyne, the fundamental or harmonics of a strong local transmitter beating with incoming signals to a frequency which may be amplified by the receiver, the beats being rectified by the heart valve.

For the above reasons the R.g.29c embodies no valve-heart.

The actual aerial circuit arrangement employed for cardioid reception is shewn in simplified form in Fig. 2. It is sufficiently standard to call only for the following comment.

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The resistance " R " must be large enough to mask the reactance of the vertical aerial circuit at all working frequencies. On the other hand it must not be too large to permit of the vertical aerial current inducing the required E.M.F. in the frame circuit.

To effect the necessary compromise over a wave range of 500 to 1,200 metres, the switch " S " is inserted. When the latter is in position 1, the two windings L and L' are in parallel, and tune a normal single-wire aerial of 100 feet length to 700 metres. In position 2, only L is in use, giving the vertical aerial a natural wavelength of 900 metres. In position 3, L and L' are in series, tuning the vertical aerial to 1,100 metres.

Brief consideration will show that by setting " S " as follows :—

Position	1	for wavelengths	500/800 metres.
,,	2	,, ,,	800/1,000 ,,
,,	3	,, ,,	1,000/1,200 ,,

then the maximum value of vertical aerial reactance which arises is much limited. It has been found possible by this precaution and with a vertical aerial of 100 feet total length, to achieve excellent cardioid diagrams on all wavelengths between 500/1,200 metres with the value of " R " fixed at 3,000 ohms.

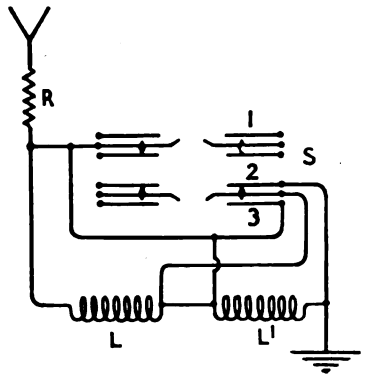

FIG. 2.

The complete circuit diagram of the receiver is shown in Fig. 3.

In the following the circuits are dealt with in the order in which they are mounted in the screening compartments, starting with the left-hand compartment. Reference is made to the photograph in identifying control handles.

Compartment 1.—This compartment contains the aerial circuit. On the left of it are mounted : (A) the terminals for connecting up the frame aerial ; (B) three sockets, into one of which the vertical aerial is inserted, according to the type of diagram of reception required ; and (C) the earth terminal.

It will be seen that the tuning condenser is used to tune either the frame aerial or the vertical aerial, according to the position of the " directive-nondirective " switch (situated on the top left-hand corner of the receiver). With the switch at " directive," cardioid or figure eight working is selected by placing the vertical aerial plug into the appropriately marked socket. On switching to " non-directive," the vertical aerial should be plugged into the " non-directive " socket.

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Immediately below the "directive-nondirective" switch will be seen two switching keys. One of these is the series-parallel switch "S" controlling the inductance in the vertical aerial circuit when working "cardioid." The other switches in or out a loading condenser in parallel with the aerial tuning condenser. Between these two keys and the tuning condenser is situated the variable coupling for achieving the necessary balance between open aerial and frame signals for cardioid working.

Compartment 2.—This contains a variable coupling coil which forms part of the tuned aerial circuit, and a tuned intermediate circuit into which the former couples. The coupling coil is controlled by the handle immediately above the intermediate circuit tuning condenser (the second tuning condenser from the left). The switch above the variable coupling provides a means of cutting out the intermediate circuit when not required. In this case the variable coupling to the intermediate circuit is replaced by a similar variable coupling to the H.F. grid circuit.

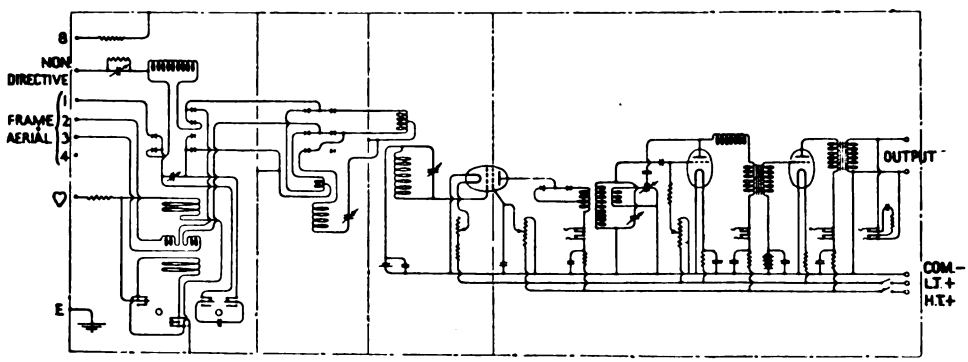

FIG. 3.

Compartment 3.—This contains the tuned H.F. grid circuit. Above the variable condenser tuning this circuit will be seen the variable coupling from the previous circuit (either aerial or intermediate according to whether the latter is "out" or "in").

Above this variable coupling is a variable filament resistance for the H.F. valve. This provides a useful volume control.

The H.F. valve is mounted horizontally between the 3rd and 4th compartments.

Compartment 4.—This contains the tuned circuit coupling the detector and the H.F. valve, together with the detector and L.F. valves, and associated components. On the front of this compartment will be seen the tuning condenser, the reaction control condenser, main "on-off" switch, and the telephone and valve feed sockets,

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all readily identifiable in the photograph. Immediately above the tuning condenser is the "C.W.-Telephony" switch shown in the circuit diagram. The object of this switch is as follows :—

In the C.W. position (*i.e.*, when the rectifier is used in a condition of self-oscillation) it limits the coupling between the H.F. and detector stages so that re-radiation of the local oscillation is avoided, and so that the beat tone being received is unaltered by tuning through the predetector circuits.

In the "telephony" position, where so rigid a limit is not imposed on the coupling between H.F. and detector valves, it increases this coupling to give the best compromise between gain and selectivity.

On the right of this compartment are situated the supply terminals, and output terminals. The latter are for permanent connection to line-linking-equipment, a monitoring point being supplied by the telephone jack on the front of the receiver.

Only a single H.T. supply of approximately 11 m/a. at 120 volts is necessary, the screen-grid voltage being obtained from a potentiometer inside the receiver.

The receiver, as standard, employs 2 volt valves working from a 4-volt supply, the necessary breakdown resistance being inside the receiver.

Frame Aerial.

This is a very robust unit.

Reference to the photograph will show that it is fitted with a control wheel by means of which the frame can easily be rotated by an operator sitting in front of the receiver.

A webbed connector is provided for linking this frame to the receiver.

The frame carries a rotating scale, which may be set relative to the axis of the frame after the position of the pedestal has been fixed.

Connection from the frame winding to the terminal block on the frame does not depend on brush contacts.

A permanent connection is effected via a cable, and a stop device is fitted to the frame which permits its rotation through 375 degrees.

This ensures ability to rotate the frame through a minimum even if this occurs after 360 degrees of rotation, and at the same time prevents undue twisting of the connecting cable.

R. B. ARMSTRONG.

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MARCONI NEWS AND NOTES

IMPERIAL DELEGATES AT MARCONI BEAM STATIONS

With the Imperial Conference delegates at Bridgwater Beam Station. Left to right (front row): Mrs. J. H. Thomas; the Rt. Hon. J. H. Thomas, Secretary of State for the Dominions; Marchesa Marconi; Marchese Marconi; and Mrs. F. R. S. Balfour. To the left of Marchesa Marconi in the second row is the Earl of Midleton; and to the left of Mr. J. H. Thomas is Mr. W. Lunn, Under-Secretary of State for the Dominions.

DELEGATES to the Imperial Conference in London visited the Marconi short wave Beam stations at Dorchester and Bridgwater as the guests of Imperial and International Communications Limited on Saturday, November 8th.

At Dorchester the delegates inspected the seven Beam transmitters which are engaged in commercial telegraphic communication with North and South America, Egypt, Japan and the Far East, and had an opportunity of seeing the compactness and ingenuity of the Beam aerial and feeder system.

At Bridgwater they witnessed the first public demonstration of Beam wireless telephony direct to Canada by means of the Marconi-Mathieu Multiplex system. For this demonstration a Post Office telephone and loud speakers were installed in a large marquee adjoining the station buildings. Here, seated at a table with the telephone, Mr. J. H. Thomas, Secretary of State for the Dominions, spoke for some time to Mr. E. W. Beatty, President of the Canadian Pacific Railway, at his office in Montreal. They conversed with the greatest ease, as was evident to all the

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visitors by the loud speaker reproduction of their talk. Mr. and Mrs. Thomas also spoke to their son and daughter in Ottawa, and other guests exchanged greetings with friends in Canada.

Transmission for these conversations was effected through the Multiplex system at the Marconi short wave Beam station at Bodmin, the reception being carried out at the Bridgwater station.

Marconi Beam Developments.

After luncheon at Weymouth, Sir Basil Blackett, Chairman of Imperial and International Communications Limited, welcomed the delegates and said the Communications Company was not merely a symbol but also an agent of Imperial unity. By means of their wireless stations Dominion talked with Dominion, Colony with Colony, and all of them with the Mother Country. The unity of the Empire depended more on communications than anything else.

Referring to the two stations visited during the day, he said : " The Dorchester station, which you have seen this morning, and the Bridgwater station, which you will see this afternoon, are two of the first stations erected to work on short waves with Beam aerials. Brought into being through the experimental work of the Marchese Marconi and his assistants and through the faith placed in them by the Marconi Company, these stations have revolutionised wireless, for until they were erected no commercial stations utilising short waves and directive wireless had as yet been used. The leadership then held—for these stations were built as long ago as 1926—has since then been fully maintained. The stations have been kept up to date, and every useful invention or improvement which has been developed during the past years has been, or is being, installed.

" Substantial improvements have been made in Beam aerials, resulting in greater concentration of the rays in the vertical plane. Modulation has been provided to the transmitters, thereby reducing rapid fading. Adaptation has been provided so that telephony can be at once made use of where required. Methods have been adopted whereby Multiplex working can be effected, enabling two telegraph channels and one telephone channel to be served from the same transmitter simultaneously. The constancy of the carrier frequency—which was already very good—has been, or is being, substantially improved.

Facsimile by Beam.

" Facsimile has just been installed on the South African circuit, and the Canadian circuit, and will shortly be installed on the other Imperial circuits. This enables a cheque or any document to be faithfully reproduced at the receiving end, no matter what the distance may be between the two stations. A few weeks ago the Beam from Australia transmitted experimentally a photograph of Commander

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Kingsford-Smith on his arrival in Australia. It was published in *The Times*. A few days ago a letter from Mr. Bennett was sent in facsimile to Canada by the Canadian Beam. I may justly say that the Empire has been provided with the finest system of wireless communications in the world, and I am confident that—thanks to the work of operators, technicians and research workers, among whom there stands out pre-eminent our Director the Marchese Marconi—this country's leadership in the sphere of wireless communications is being maintained and will be maintained in the future."

Sir Basil Blackett added that in 1929 the cable and wireless systems of Imperial and International Communications Limited carried 104,000,000 words between Empire countries, and 73,000,000 words between Empire and foreign countries.

Replying on behalf of the delegates, Mr. J. H. Thomas said he was proud to be the guest of a Company with whose name was linked the name of Marchese Marconi, " who will be remembered long after politicians and statesmen have been forgotten."

Irish Broadcasting Development.

The Irish Free State authorities have placed an order with the Marconi Company for the supply of a high power broadcasting transmitter, which will be erected in a central position in the Irish Free State to serve the whole of the Dominion. The new transmitter, which is to be manufactured at the Marconi Works at Chelmsford, will embody the latest refinements of broadcasting technique. With an aerial energy of 60 kilowatts it will be one of the most powerful broadcasting transmitters in Europe, while arrangements have been made to enable the aerial energy to be doubled at a later date if required.

The frequency emitted by the station will be maintained by an oscillating quartz crystal, thermostatically controlled. The principle of low-power modulation will be employed. This will ensure the constancy of the transmitted wavelength within very fine limits, an essential condition of modern broadcasting, which requires transmitting stations to adhere strictly to their allotted wavelengths.

The aerial will be suspended between two lattice steel masts each 330 feet in height. It will be situated at a considerable distance from the transmitting building, and, in accordance with modern practice, the energy from the transmitter will be conveyed by a feeder to a small building situated directly under the aerial, where the energy is transferred to the aerial system by a coupling device.

The wavelength for the new station, which is expected to begin operation in the autumn of 1931, will probably be 413 metres.

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Marconi Veterans' Third Annual Reunion Dinner.

This popular function was held at the Holborn Restaurant on the 14th November last, Mr. H. W. Allen, the Secretary of the original Marconi Company—the Wireless Telegraph and Signal Co., Ltd.—being in the Chair.

Of 76 veterans on the roll, there were 55 present.

Marchese Marconi as chief guest was heartily welcomed, as it was realised that the important work on which he had been engaged in Italy might have prevented his appearance this year. Another guest of honour was Mr. A. Carpmael, representing Messrs. Carpmael and Ransford, the firm of patent agents who in 1896 filed the first Marconi patent in England, and are still acting as patent agents for the Marconi Co. Mr. K. Poupart, a veteran of 1902 from the Belgian Co., was another welcome guest, having travelled from Belgium specially for the occasion.

Letters and telegrams of regret were received from Sir Ambrose Fleming, Marchese Solari, and others.

The toast of " Our Guests " was proposed by Mr. H. W. Allen, and was suitably responded to by Marchese Marconi ; and Mr. F. S. Hayburn in an excellent speech proposed the health of the Chairman to which Mr. H. W. Allen replied.

The proceedings were enlivened by a first-class musical programme, and it was agreed by everyone that the reunion was a great success.

The election of officers for the ensuing year took place at a general meeting of veterans held at Marconi House on the 14th October, when Mr. H. W. Allen was appointed Chairman, Mr. C. E. Rickard, Deputy Chairman, Mr. H. M. Dowsett, Secretary, and Mr. W. J. Collop, Treasurer.

It was unanimously decided at this meeting that the qualification of a member should be :—" A total of twenty-five years' service with one or more of the companies in the Marconi Group or elsewhere in the interests of that group."

The Veterans' Roll has accordingly been corrected from this standpoint and the revised list is published in this issue.

This decision has been communicated to some 18 foreign companies associated with the Marconi Co., and the names of veterans in their service entitled to be included on the roll will be entered thereon in due course.

New European Broadcasting Stations.

Marconi Broadcasting stations are also to be installed in the near future at Trieste, Italy, and Viipuri, Finland.

The Italian broadcasting station, which is to be erected in accordance with the Italian Broadcasting Company's plan for the development of its service, will

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1895

Marchese G. Marconi

1897

Col. H. Jameson Davis, H. W. Allen, G. S. Kemp,

1898

P. W. Paget, C. E. Rickard, R. F. Cave,

1899

W. Densham, Andrew Gray, H. M. Dowsett, R. T. Munson,

F. S. Stacey, F. Woodhouse, C. S. Franklin, P. J. Woodward, A. B. Blinkhorn,

1900

H. W. Corby, R. N. Vyvyan, A. J. Clark, F. Archer, J. Harvie Clark,

Sir. Ambrose Fleming, A. H. Atkinson, E. E. Triggs,

1901

W. S. Entwistle, W. J. Willey, G. H. Green, A. Eve, F. J. Leathers,

Capt. C. V. Daly, G. Pells, E. G. Tyler, F. E. D. Pereira, F. K. May, A. H. Ginman,

1902

E. Berry, W. F. Thomas, R. D. Bangay, F. E. Burrowes, W. Davies,

Capt. H. J. Round, H. A. Ewen, E. C. Richardson, A. A. Kift, J. Lewis,

1903

D. W. Tullock, J. R. Stapleton, F. Jones, J. Harvey,

A. J. Huff, H. T. Worrall, E. T. Hills,

1904

H. J. Tattersall, A. J. Irvene, T. Iddon, W. A. Taylor, W. I. McGhee,

J. R. Robinson, W. Platt, W. J. Collop, W. N. Ball, F. S. Hayburn,

P. L. Rowland, A. Cappelaere, W. Tasker, H. Cornwall,

1905

S. C. Parish, J. N. Johnson, W. B. Cole, E. J. Wagstaff, G. A. Manson,

C. A. Mason, H. M. Burrows, C. James, F. W. M. Herring.

Marconi Veterans' Roll.

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have an aerial energy of 15 kilowatts, C.C.I.R. rating, with a maximum modulation of 100 per cent. It is designed to cover broadcasting wavebands between 200 and 545 metres, but the normal working wavelength of the station will be 247·7 metres. Low power modulation is provided.

A new type of valve drive, which has been developed in the Marconi Research laboratories, will be incorporated in the new Trieste transmitter and this will ensure a constancy of carrier wavelength well within the limits specified at the Hague Conference of 1929.

The Finnish Broadcasting Station.

The Broadcasting station for Finland will have an aerial energy of 13·2 kilowatts C.C.I.R. rating at 80 per cent. modulation. The transmitter is of similar design to that which is to be installed at Trieste, but the frequency control will incorporate an oscillating crystal instead of the valve drive control.

An oscillating crystal enclosed in a thermostatically controlled heat insulated box is employed in this system to provide the drive frequency of the station. The thermostat box ensures the minimum variation of the rate of oscillation of the crystal, so that the transmitted wavelength remains quite steady.

When the new station is completed simultaneous broadcast transmissions will take place from Viipuri and the existing Finnish station at Helsingfors, and for this purpose suitable land-line and speech control equipment is being supplied by the Marconi Company.

Marconi "Talkie" Apparatus.

One of the latest developments in electrical sound reproduction is in connection with talking pictures, and in this field researches carried out by the Marconi Company have resulted in the development of inventions for sound recording apparatus for cinematograph films which are acknowledged to be far ahead of anything previously attained.

Those who know of the results obtained by Captain H. J. Round in electrical recording for gramophone records will not be surprised to hear that the film recording apparatus, which also embodies inventions resulting from his researches, is regarded as the most efficient apparatus of its kind yet produced.

The Stoll Picture Production Company, one of the most important cinematograph interests in Great Britain, which is manufacturing this apparatus under patent licence from the Marconi Company, is the first to use this system, which has been given the name of " Visatone " and has been installed in the Stoll Studios in London,

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One picture, " Such is the Law," has already been made with talk and sound effects by the Visatone process, and the film critics of the leading British newspapers have written enthusiastically of the new reproduction system.

" Extraordinary Purity."

" Spotlight," of the *Sunday Referee*, made the following comments in a recent issue :—

" An entirely new and entirely British system of talking picture production has been installed on the new sound stage which is now at work in the Stoll Studios at Cricklewood.

" The reproduction by this Stoll process, which is called Visatone, and which has been perfected under patent licence from Marconi, is as fine as anything I have heard. Most notably there is a complete absence of ground hum or burr and entire freedom from blasting. Moreover, it seemed to me that voices were more natural and less mechanical than by any other system. Visatone appeared to me to have gone further from the mechanical and nearer to the real than anything else. In short, from what I have experienced, I should say that Visatone is the Rolls-Royce system. It has complete freedom of movement on the film stage. It has quite extraordinary purity of tone in the theatre. It has apparently complete reliability in the laboratory. The absence of the first and the last of these virtues has entailed. many studio headaches in numerous other instances. The absence of the second has caused many headaches elsewhere."

" Subtlety and Distinctness of Tone."

The film critic of the London *Times* gave the system his considered appreciation in the following terms :—

" Judged by this production the new system, operated under a patent licence from the Marconi Company, need not fear comparison with any other method now in use. In subtlety and distinctness of tone it left little to be desired."

The principal cinematograph trade newspapers were greatly impressed with the technical excellence of the Visatone reproduction. The following extract from *To-day's Cinema* of November 15th typifies trade opinion :—

" Something of a sensation was caused at the trade show yesterday of the first picture made by the Visatone process.

" The recording in this picture rivals that of any system yet heard, although the film was made within a few weeks of the installation being completed, and by sound engineers who were not experienced in the actual technique of talkie making.

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" At the Palace trade show, dialogue was clear-cut and every word plainly audible ; the difficult ' s ' and ' f ' sounds which are the crucial tests of a recording system reached a high degree of purity.

" The system is that of Marconi's Wireless Telegraph Company, Limited.

" The apparatus, designed by Captain H. J. Round, entirely justifies Sir Oswald Stoll's enterprise in deciding to equip the studio with Visatone."

North Sea Navigation by Wireless.

Valuable navigational assistance given by the Marconi Direction Finder on a North Sea passage in a dense fog is reported by a London Trinity House pilot, who comments on the relief it was to have such an instrument aboard the ship. The pilot reports that the Commonwealth and Dominion Line steamship " Port Denison " on passage from Middlesbrough to Hamburg left Tees Bay in a dense fog and set course S.72 E. direct for Elbe No. 1 Lightship at a distance of 320 miles.

" After running 22 hours," he records, " we got bearing of Borkum Riff which put the ship 13 miles ahead of the patent log. We got two other bearings on Borkum Riff and with the last also a bearing on Nordholz which made an excellent cross. After about an hour we got a bearing on Norddeich which fitted in well with the others.

" I consequently altered the course to pass four miles north of Nordeney Lightship and picked it up exactly where I wanted, the bearings being absolutely accurate. This was the first mark we had seen since the Fairway Buoy in Tees Bay, and after the ship had been going at various speeds, slow, half, stop, etc., and running across the tides, it speaks volumes for the accuracy of the Direction Finder. I can only say it was a great relief to have such an instrument aboard the ship in the dense fog we had on the passage across."

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THE MARCONI REVIEW

December, 1930

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THE MARCONI REVIEW

No. 27. *December, 1930.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

REVIEW OF COMMERCIAL WIRELESS DEVELOPMENT

BY C. E. RICKARD, O.B.E.

By the courtesy of the Institution of Electrical Engineers, we are able to reproduce below the address given on November 5th, 1930, by Mr. C. E. Rickard, O.B.E., M.I.Mech.E., M.I.E.E., Deputy Engineer in Chief of the Marconi Company, on his election as Chairman of the Wireless Section of the Institution for the year 1930-31.

I FEEL that my first duty this evening is to express my great appreciation of the honour the Wireless Section has done me in electing me to serve as its Chairman for the present Session.

When I look back on the line of distinguished men who have preceded me, and on the splendid work that has been accomplished under their guidance, I feel that the high standard set by them will be very difficult for me to emulate.

A few years ago one of our past Chairmen remarked that the Wireless Section had not been in existence long enough to have a tradition, but since then we have built up a tradition in which we may take pride. We are now entering our second decade of existence full of vigour, with a membership of 529, backed by a splendid record of interesting papers and discussion in the past, and well-attended meetings.

During the past Session the Council has approved the extension of the activities of the Section to include under-water sound signalling and depth-sounding, communication by infra-red or light rays, and electrical recording and reproduction of sound as subjects appertaining to the Wireless Section. This additional scope should add further interest to our activities, and we hope that very interesting discussions and exchange of information will develop in due course.

Coming now to the subject of my Address this evening, I think I may safely assume that when inviting me to take this chair you had in mind my association with the development of commercial wireless telegraph communication and the manufacture of wireless transmitting and receiving gear for commercial services, and it is accordingly that part of the wireless art with which I propose to deal.

Speaking of wireless as it strikes the popular imagination, I noticed a few weeks ago that one of our leading daily papers, referring to the recent very interesting and successful public exhibition at Olympia, spoke of wireless as though it had been in existence for only 10 years, which made me wonder what we had been doing during some 20 odd "pre-wireless" years.

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There is no doubt that the advent of broadcasting, to which the newspaper referred, gave a great impetus to the study of radio engineering, and the development of this science in all its branches is proceeding by leaps and bounds. Not all of the inventions or improvements relating to broadcasting are applicable to wireless telegraphy, but there is no doubt that the great advances made in broadcasting as a public service have placed at the disposition of the wireless telegraph and telephone engineer a vast selection of valves and circuits, and a variety of technique which would not otherwise have been developed.

Marine Communication.

Marine communication was the first form of wireless telegraphy to be developed on a commercial basis and, in spite of its powerful rivals in the public imagination, I am still of the opinion that it is the most important application of wireless, for the simple physical reason that wireless supplies a means of communication with moving objects, particularly with ships and aircraft, which can be achieved in no other manner. The contribution of wireless to the safety of life and property, and its assistance to navigation are so obvious and so well demonstrated that should there arrive, at some future time, any danger to mobile communication, due to ether congestion, in so far as the essential safety of life at sea or in the air is concerned, I feel certain that international opinion would continue to give marine communication the first consideration, and other forms of wireless communication would be called upon to give way.

These ideas are of course ever present in the minds of the international legislators who frame the rules and regulations of radio-electric communication, and who also demand that marine wireless telegraphy shall progressively improve and keep in step, so far as is economically possible, with modern progress.

Commenting upon the progress of marine communication we may say that about half (approximately 14,000) of the world's ships are fitted with wireless apparatus. Of these about 10 per cent. are fitted with valve transmitters and the remainder with spark only. Spark transmitters of 100 watts input power are considered to provide the best form of emergency apparatus, probably on the principle that the most strident and hoarse cry for help is likely to attract the most attention. Since the 1st January, 1930, in accordance with the Washington Regulations, no new spark transmitters of greater power than 300 watts input power are permitted to be installed, and from now onwards the percentage of high-power spark stations on board ship must of necessity decrease steadily.

The use of short waves for very long-distance communication between ship and shore is being recognised, and the number of ships fitted with short-wave apparatus is steadily increasing, the present-day estimate being about 150 ships fitted with transmitters and three times that number with receivers only.

The fitting of automatic alarm devices on board certain ships where a permanent watch is not kept has been carried out in accordance with the Safety of Life at Sea Convention, and there are now approximately 1,200 ships fitted with this apparatus which enables a ship's operator to be called to his post, when he is not on watch, by the ringing of a bell actuated by the reception of the alarm signal which nowadays precedes the S O S call.

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There were also some 450 to 500 ships' lifeboats fitted with wireless up to the end of last year.

Apart from the large number of vessels which are compulsorily fitted, in accordance with the regulations of the Safety of Life at Sea Convention, or of the laws of the countries with which, or under whose flag, they trade, there is an increasing number of vessels which carry wireless apparatus although under no legal obligation to do so. In particular I refer to vessels which do not carry passengers, and are of less than 1,600 tons gross tonnage. It is obvious in these cases that wireless is carried solely for its utility in the navigation and exploitation of the ship. Among these are a large number of trawlers, whalers and other vessels engaged in the fishing industry who find that wireless apparatus for communication or for direction finding purposes is a valuable aid to their industry, and the equipment of vessels of this kind is rapidly on the increase.

So far as marine direction finding is concerned, the wireless direction finder is now recognised as a navigational instrument of such importance that at the International Conference for the Safety of Life at Sea, held in London last year, an agreement that all passenger vessels of 5,000 tons or over must be fitted with direction finders was signed by 18 nations, and is to come into force as from the 1st July, 1931.

According to the best estimates available there are at present well over 3,000 vessels equipped with direction finders, or over one-fifth of the total number of vessels carrying wireless.

Side by side with the ship direction finder, the installation of automatic wireless beacons around the coasts of the leading maritime countries of the world has made rapid progress. The function of the wireless beacon is to send out a recognised signal at convenient intervals, purely for the purpose of enabling ships fitted with direction finders to take their bearings and thereby to find their exact position when approaching the coast. Such stations work on wavelengths between 950 and 1,050 metres, and are distinguished by their call signals, the form of signal emitted, and by their musical notes.

At present there are in operation around the coasts of Great Britain and Ireland 15 automatic wireless beacons. Five more are in course of construction, and the number spread over the world is estimated to be about 200.

Rotating Beacons.

As a further aid to navigation an important development has been that of the rotating beacon, to which the Radio Research Board has devoted a good deal of attention.

The results of systematic tests showed that ships and aircraft fitted with ordinary receiving apparatus could obtain their bearings from rotating beacons with sufficient accuracy for navigational purposes, subject to the usual night effects. For small coasting and fishing vessels and for aircraft purposes the rotating beacon has important advantages, in the former case because it avoids for the small shipowner the cost of the ship direction finding apparatus, and in the latter because the aircraft direction finder solution is not entirely complete or satisfactory, and there are still some difficulties and limitations to be overcome in certain cases ; moreover, every ounce of extra weight carried is an important consideration.

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Adcock Direction Finder.

Shore direction finding stations as an alternative to rotating beacons or direction indicators have a considerable importance in the field of mobile communications, and there are a number of stations in service both for marine and for aircraft services.

Most of such stations have up to the present been equipped with apparatus of the Bellini-Tosi type, but recently a very notable advance has been made by the development of the Adcock principle, which enables night errors to be eliminated. In this field important investigations have been made by the Radio Research Board.

Parallel work on somewhat different lines had been carried out by the Research Department of the Marconi Co. on the directional characteristics of incoming radiation, on *short* wavelengths. Following their achievements in this field, they decided to carry the technique of their short wave Adcock direction finder into the field of medium wavelengths on which radio navigation is carried out. Certain modifications to the method of screening the horizontal leads from the vertical aerials became necessary, as for an accurate navigational instrument the condition of non-radiating screens had to be allied with close electrical symmetry. This was successfully accomplished, and prolonged tests with the new direction finder showed the possibility, on wavelengths of the order of 1,000 metres, of obtaining a night accuracy of 2° to 3°. This result is of the highest importance, when it is realised that hitherto it has not been possible, with practical commercial instruments, to give an absolute guarantee of their accuracy on continuous waves during the night period. This has an important bearing on aircraft navigation.

Comparative tests recently made with aircraft after sunset, during night effect conditions, over a distance of more than 50 miles, showed that the limit of error was ± 3° with the Adcock arrangement, whereas with the Bellini-Tosi method only one-third of the observations made gave bearings of an accuracy within ± 3°, and errors were shown up to approximately 90°. In other words, two-thirds of the Bellini-Tosi bearings had errors of ± 5° or more.

The very convincing results obtained by the development of the Adcock principle into an instrument of a practical form, which on medium wavelengths can be guaranteed to be free from night effect errors, is considered to be so important and so definite an advance that it is thought unlikely that future coast or aerodrome stations will be fitted with Bellini-Tosi aerials.

On the other hand, the rigging and top hamper of sea-going vessels is a definite obstacle to the application of the Adcock principle on board ship, and it is considered very unlikely that the Adcock aerial will supersede the rotating-loop or Bellini-Tosi aerials for marine direction finding purposes.

Equi-Signal Radio Beacon.

Another direction finding problem peculiar to aircraft is that of "homing," or flying to and approaching an aerodrome. In this case a pilot does not so much desire to know his position as defined by bearings on two fixed stations, which may perhaps involve reference to a map, as to know in particular whether he is flying direct to his destination. Since 1920 the American Bureau of Standards has been developing a method of directional transmission which would serve this particular purpose.

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The underlying principle of the American radio beacon system may be briefly stated as follows: Two directive aerials are placed at an angle with each other. Along the line bisecting this angle the radiation from each aerial is equal. At any other point radiation is stronger from one than from the other. If, therefore, the separate radiations of the two directional aerials can be clearly designated, it becomes possible by observing the combined radiation of the system to follow the course along the bi-sector referred to.

A very practical form of such a beacon was produced, known as an aural equi-signal radio beacon. It consisted of a Bellini-Tosi aerial system excited through two separate radiogoniometers set at 90° or less to each other. The radiation via the two radiogoniometers was distinguished by the letters "N" and "A," and the keying was interlocked in such a manner that equal reception of the two radiations combined to form a continuous dash. This dash indicated to the receiver that he was placed exactly on the line bisecting the angle between the two figure-of-eight diagrams of radiation. Displacement to the left or right of this line was indicated by reception of either the letter "N" or "A." Several such beacons are now in operation in the United States for point-to-point navigation of aircraft.

The Bureau of Standards of America have also made experiments with beacons in which the separate directional radiations are designated by different modulated frequencies. The output circuit of the receiver developed to work in conjunction with such beacons is fed to two reed indicators, the first of which is resonant to one frequency of modulation, and the second to the other. If, therefore, the receiver is placed on the line bisecting two such radiations, both reeds vibrate equally, whilst a displacement to the right or left of the line coincides with a reduction in amplitude of vibration of one reed and an augmentation of the other, and vice versa.

Ship Telephony.

Ship-to-ship telephony is in common use between trawlers and whalers and other types of vessels, and ship-to-shore telephony has been successfully carried out on many occasions previously, but perhaps the most interesting development in marine communication during the past twelve months has been the combined effort made by the British Post Office on this side of the Atlantic, the American Telephone and Telegraph Co. in the United States, and the Marine Communication Companies and their associated manufacturing Companies to try out a public ship-to-shore radiophone service. So excellent and comprehensive an address was given a few months ago by Sir Thomas Purves to the London Students' Section that there is little I can add on this subject.

Compared with transatlantic telephony, the obvious transmission handicaps of telephony from shore to shipboard in the Atlantic are (1) the economic limit to the power of the ship's transmitter; (2) the lack of the multiplying factor of beam aerials both for the transmitter and the receiver on board; and (3) the continually changing distances over which it is required to work. The small space available for the installation not only limits the power of the transmitter but has a bearing in some cases on the number of wavelengths it is practicable to employ to meet the changing conditions of distance, of night and day working, and of the seasons of the year.

Another drawback is the fact that, owing to the changing direction of the ships from the shore stations, the fullest advantage of directional beam working

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cannot be taken at the shore end. There are further difficulties due to the fact that those ships with which a ship-to-shore telephony service is most desirable are those with which it is also necessary to maintain the best telegraph service, which entails simultaneous working on short wave telegraph sets for arbitrage or Stock Exchange services, medium long wave working on 1,875 to 3,000 metres for long distances ; 600 to 800 metres working on interrupted continuous waves for normal ship communication purposes, and reception of news on long waves from Rugby and other news-disseminating stations. All of these things are desirable and are accomplished to a certain extent, but the problem of interference to the short wave telephony service from the long wave ship transmitter on continuous or interrupted continuous waves is serious.

The type of continuous wave transmitter that it is economically possible, or even practicable, to install on shipboard is a generator of numerous harmonics, and it requires co-operation between telephonist and telegraphist on board to avoid interference, and a certain amount of juggling with wavelengths to prevent a harmonic of the long wave set interfering with telephony. Perhaps the most difficult problem which has arisen is the fact that the powerful radiation from the short wave transmitting aerial generates oscillations in all loose conductors about the ship. These conductors re-radiate and, given the vast number of possible modes of vibration, there is practically certain to be interference with the incoming telephony wave. Bonding of stays and conductors has been resorted to, but this is a difficult job and it is usually impossible to trace the particular conductor or combination of conductors causing the interference. Some ships are worse than others in this respect. These parasitic re-radiations behave somewhat similarly to atmospherics, and the best solution appears to be to suppress the cause, that is to say to suppress, or rather to reduce greatly, the carrier of the transmitted wave during reception.

Reviewing the situation, I think we must look upon the work done up to the present with regard to ship-to-shore telephony as a series of successful experiments which have shown the direction in which we must proceed. I believe it can be said to be established that 4-wire working at the ship end is merely a stepping stone and that we must face the expense of 2-wire working, and the use of a telephone terminal equipment on board, if a satisfactory service is to be attained. With regard to the number of wavelengths required—a problem which affects the manufacturer and legislator concerned with the repartition of the ether—it is at present considered that 5 wavelengths are advisable if a continuous service is to be obtained, day and night, winter and summer, and at the varying distances from land over which communication has to be made. Such wavelengths as are being catered for at the moment by the Rugby and American shore stations are 17, 23, 34, 63 and 90 metres approximately. Experience is not sufficient to establish these definitely, and it may be that 26½ metres as a compromise between 23 and 34 and 75 metres as a compromise between 63 and 90, will be found sufficient for commercial purposes when further experience is gained, or some other compromise may be found sufficient for ordinary purposes, thus reducing the wavelength requirements to three.

Slightly separated wavelengths are required for the shore stations in America and Europe to allow simultaneous conversations to be carried on from either side of the Atlantic, and ship stations require to be able to make slight adjustments to each of their waves to enable them to call either Rugby or New York.

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The selection of wavelengths for the ship telephony service is complicated by the presence on board ship of short wave installations working telegraphy ; and in fact the selection of wavelengths and the organisation of all short wave services is becoming so delicate a matter that it is to-day a specialist's job.

It seems certain that the study of ship-to-shore telephony organisation, and frequency allocations, will provide an interesting and, at the same time, arduous task for the experts of the International Technical Consulting Committee, who meet again next year at Copenhagen.

Design and Development of Portable and Semi-Portable Apparatus for Mobile Services.

Transmitters.

In the field of wireless engineering concerned with small and medium-power general purpose transmitters, activity has centred chiefly in the last few years in the development of circuits to make possible the application of short waves. Naval, military and aviation authorities, as well as civil authorities responsible for the maintenance of communication between small isolated centres, have been quick to appreciate the great saving in power and cost of transmitters made possible by the use of short waves, and, further, the possibility of communicating over distances quite outside the range of medium-wave transmitters of a practicable power, size and economic cost.

In the class of transmitter under consideration, the types vary from pack sets employing hand-generators to fixed or mobile stations of the order of 3 kw. aerial power, but in every case the prime requirements are a large choice of transmitting wavelengths and simplicity of operation, the latter being of the utmost importance, since this class of transmitter has frequently to be operated by entirely unskilled personnel.

Arising out of these requirements the problem most difficult of simple solution, from about 75 metres downwards, is the tuning of the aerial circuit.

Two methods are in general use :—

(A) To employ a variable length of aerial, using an insulated winch, and so to adjust its length that the wavelength of aerial plus loading and coupling coils is one-quarter or three-quarters of the transmitted wavelength.

(B) To use a fixed length of aerial and to provide at its base a variable impedance capable of terminating correctly the aerial for any distribution of standing waves along its length.

Method (A) gives better average radiation but is impracticable in many cases, *e.g.*, a submarine ; while method (B) lends itself to extreme simplicity of adjustment, and for this reason, and also because it is simpler to rig, it is more frequently employed, in spite of poorer average radiation.

One important aspect of the introduction of short waves into this class of transmitter is that whereas previously, on medium wavelengths, reliable telephonic communication has been possible with simple self-oscillators, this is not the case on short wavelengths, due to distortion during propagation resulting from variations in the carrier frequency caused by modulation.

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Most short wave transmitters of this class, therefore, employ only C.W.* and I.C.W.† telegraphy, but for some services a demand exists for telephonic communication, and thus the difficulties of design have been greatly increased by having to provide a master oscillator the frequency of which will be unaffected by modulation of a subsequent amplifying stage. Also, international regulations as to constancy of frequency now make it necessary to employ master oscillators having a high degree of constancy for certain services catered for by this class of transmitters.

A modern example of a transmitter designed to cover all these varied requirements is a crystal-controlled set, the main data of which are as follows :—

Wave range. 16 to 75 metres.

Master oscillator. Choice, by external switch, of a valve oscillator giving continuous wave range, or three short waves by crystals. Valve oscillator and crystals enclosed in thermostatically controlled box. By suitable doubling and trebling in subsequent stages valve oscillator covers wave range in one sweep of variable condenser.

Aerial power. C.W. 350 watts ; I.C.W. and telephony, 120 watts.

Instantaneous selection of C.W., I.C.W. or telephony by 3-position switch.

Keying. By self-absorber method, up to 150 words per minute.

75 per cent. modulation on telephony—sensibly linear.

Aerials. A single length of aerial can be employed for whole wave range, but, naturally, when working wavelengths have been decided upon, aerials would be used having good radiation at those wavelengths.

Carrier frequency. Constant to 1 in 10,000.

Time to change from one frequency to another. Five minutes in worst cases.

Size. 5 ft. × 5 ft. × 18 in. deep.

At the other end of the scale is a portable set for C.W. and I.C.W. telegraphy only, employing a self-oscillator, wave range 20 to 60 metres, using a hand generator as a source of power, and capable of operation by semi-skilled personnel.

Modern aerodrome ground station transmitters present special problems, the chief of which is the selection by remote control of any one of six spot wavelengths in the waveband 400 to 1,600 metres.

Still another tendency in all transmitters of this class is the elimination of batteries for auxiliary supplies, as for keying, grid bias, etc. Small rectifiers—of the metal type where possible—are used to provide these supplies from the filament alternator.

Screen-grid transmitting valves have opened up new possibilities in the simplification of circuits, since they dispense with the necessity for balancing interelectrode capacitances in multi-stage transmitters. Against this advantage must be set their lower efficiency and the requirement of a screen-grid voltage supply. In small

* Continuous wave. † Interrupted continuous wave.

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and medium power transmitters, up to say, ½ kw. aerial power, the latter is important, since it involves either a separate H.T. supply or a potentiometer across the main H.T. supply taking an amount of power which is uneconomical in proportion to the total power of the transmitter. In many cases, however, the resultant circuit simplification more than justifies the use of such valves in general purpose transmitters.

Receivers.

Coming now to general purpose receivers, the two most important influences in recent years in their progressive development have been the introduction of short waves and the arrival of the screen-grid valve. For receivers in this class the prime requirements are a wide wave range and simplicity of operation.

Development has been along two main lines :—

(A) Receivers with low damping input circuits, followed by high-gain multi-stage screen-grid valve amplifiers, with reaction definitely excluded. Separate oscillators for C.W. reception, tuned or untuned low frequency magnification at will ; or

(B) Receivers with one stage of screen-grid valve amplification, having the aerial directly coupled to the grid circuit, followed by a detector with reaction capable of self-oscillation for C.W. reception. Low frequency amplification as for (A), *i.e.*, tuned or untuned.

Type (A) is confined to medium and long waves, and development has resulted in the use of at least three stages of high frequency amplification with small gain per stage, for the reasons that such an arrangement does not depend on special care in design or testing to ensure stability, and also that the resultant high damping of this circuit enables the condensers to be ganged.

Type (B) fulfils the requirements of a great many services, and is used on short, medium and long waves. Below about 150 m. such receivers usually employ plug-in coils, to avoid stray capacitances as far as possible, but above this wavelength all coils are contained in the receiver, and the range required is selected by a switch.

A modern example of a receiver in category (B) has a wave range of 150 to 3,000 metres. Circuit development has made possible the complete ganging of the two tuning circuits, in spite of the fact that an aerial is coupled to one and reaction applied to the other, and that both are low-loss circuits, so that the tuning controls comprise a 4-position range switch, one tuning handle—calibrated directly in wavelength—and a reaction control. A drastic volume control is required on this class of receiver, because mobile service conditions frequently imply working at short ranges from powerful transmitters. Such a volume control should increase high-frequency selectivity whilst reducing high frequency gain.

Aircraft Picture Transmission.

The problem of transmitting military intelligence by means of picture telegraph apparatus between moving aircraft and a distant ground station has been investigated, and the results obtained show that the methods available are quite practical. One such apparatus recently developed possesses the following features :—

(A) Independent synchronising means at the transmitter and receiver.

(B) No photo-electric pick-up system at the transmitter.

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(c) Messages to be transmitted are written in conducting ink or very soft pencil.

(d) Messages at the transmitter and receiver remain stationary.

Actual flying experience has shown that it is possible to convey military intelligence between an aircraft and its base over distances up to 150 miles. The normal aircraft wave, using a 160-watt transmitter, is employed, and the speed of transmission is approximately 8/9 square inches per minute. With the adverse signal-to-noise ratio available on such a circuit it has been found essential to utilise separate synchronising means at the transmitter and receiver.

Let us turn now from the mobile to the fixed services.

Point-to-Point Communication.

The commercial development of point-to-point services has been continuous during the past year. On the telegraph side new circuits are being opened up for communication and the number of competitors against our international services is steadily increasing. Since the war the tendency for each nation to control its own communications becomes continuously stronger, and whereas wireless communication on long waves did *not* constitute a really serious competitor to cable companies, short wave working goes strongly ahead, and each new commercial wireless station in foreign countries takes traffic and revenue from the older methods of communication.

During the present year, however, the short wave services have not quite lived up to their reputations of the previous years, and there has been a falling off in the number of hours of recordability, due to an excessive number of magnetic storms. The year 1930 has been peculiarly severe in this respect, but it is probable that the disturbances to the short wave services will become less and less during the next 5 or 6 years, increasing again until the period of intense magnetic disturbance occurs 10 or 11 years hence, by which time we hope that some method will have been found of eliminating their effects.

As an illustration of the effects of magnetic storms on long distance short wave communication, I have selected from a series of curves an example for the months of April and May of this year (see Fig. 1). Traffic between England and Australia is sent on 26 m. waves, part of the day over the "long route" across the Atlantic and South Pacific Oceans, and part over the "short route" across Asia and the East Indies.

The rounded curve refers to the "long" route, which is the *worst* and *least used*, and shows the reduction of hours of high speed and recordable working, as compared with the incidence of magnetic storms.

Fortunately the "short" route is not so badly affected. The Indian and South African wireless circuits are hardly affected at all. It is those circuits of which the great circle between terminals passes near or over the polar regions which suffer most during magnetic storm periods.

These facts point to a solution, *i.e.*, the use of relay stations during fade-out periods in such a way that the great circle paths between terminal stations and relay stations do not approach the polar regions.

There is some reason to believe that the most suitable wavelength for communication between distant points is considerably shorter during the periods when

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magnetic storms are prevalent than in the periods of solar quiescence. Investigations are being carried on in many parts of the world in the hope of finding a solution in the use of very short waves. Also it may be stated that during the early days of experimental short wave working before the beam stations were constructed, wavelengths of 30 and 60 m. were found quite suitable for transatlantic day and night working respectively. The beam stations were originally designed for such wavelengths, which were found at a later date to be quite unsuitable.

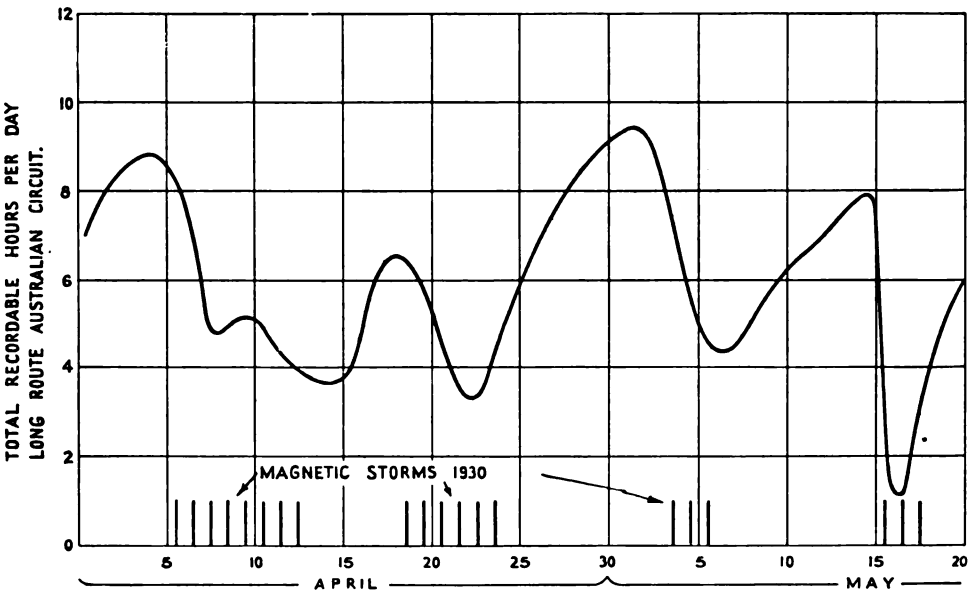

FIG. 1.

There is, therefore, a possibility that as time proceeds along the magnetic storm cycle it may be found necessary to modify the present beam station wavelengths. There is not much evidence to support this theory, but it is worthy of careful observation.

During the periods of magnetic storms it has been found on repeated occasions that while communication on short waves has failed completely during periods of 12 hours or more, communication on long waves has remained unaffected. Therefore, in spite of the higher initial cost and higher maintenance charges of high power long wave stations they still have their uses, particularly for distances up to 3,000 miles, and both the Post Office and the Imperial and International Communications Co. contemplate additional long wave stations for their communications with America, the Post Office for telephony and the Imperial and International Communications Co. for telegraphy.

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Point-to-Point Telephony.

The Post Office telephony services from Rugby continue to extend rapidly, and the dream of telephonic inter-communication between the Dominions, Colonies, and the Mother Country is in course of becoming an accomplished fact. I do not think I can add anything to the excellent papers and information which have been read and published on radio-telephone services, in particular the lecture given by Mr. G. H. Nash, C.B.E., at the Royal Society of Arts in April last, but perhaps the following remarks will be appropriate from one whose experience was confined to radio-telegraph services until comparatively recently.

Until radio-telephony was developed to the stage of entering into public service, radio communication could hardly be called an exact science. It was, of course, as exact as we could make it, but there is no doubt that the influence of telephone practice on radio practice has been very beneficial. In particular the adoption of the transmission unit (néper or decibel) and of methods of measuring amplification and losses in our apparatus has led to a great advance in technique in all directions ; for example, it is now standard practice to specify the gain in the individual parts of a receiver, the shape of the filter curves, and even the gain of beam aerials. Added to this, the habit of measurement and study of transmission phenomena has extended rapidly as a result of the more general use and progress of measuring apparatus and methods.

Development in radio practice both in measurement and in theoretical studies has made it possible to prophesy the behaviour of a proposed radio channel with increasing accuracy. The propagation phenomena in connection with waves from 15 to 40 m. have been investigated so that for a given period of the year, time of day, and wavelength employed, it is possible to prophesy with reasonable precision the conditions which will prevail at either end of a radio channel between given points. Such studies have proved of considerable value in the setting up of intercontinental wireless circuits.

Reverting to the influence of telephone practice, its value was exemplified in planning, for example, the Rugby-New York radio-telephone circuit. In operation such a circuit is treated, from the point of view of a telephonist, as if it were a metallic circuit, and in the main the circuit is treated as though it were a repeatered line.

Methods of design employed in telephone practice are now used to an increasing extent on wireless receivers and transmitters, such as rack-mounted equipment, as in repeater stations, and alarm indicating devices to show the existence and whereabouts of faults and to provide facilities for testing circuits at any point throughout the equipment, etc. It may be said that the influence of telephone practice on wireless practice, particularly as regards telephony, is due to the conditions under which telephony must work. Since a subscriber has no technical interest or appreciation of any difficulties which may arise, it is essential that there be no discontinuity in his conversation. Under these circumstances faults must be cleared with the minimum possible delay, and all levels throughout the system correctly adjusted and supervised. In pursuit of the telephonist's ideal of uniform signal intensity, a great deal of money has been spent in the effort to perfect a method of automatic volume control which will maintain a uniform level during extremes of fading without causing distortion.

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Facsimile Working.

The attainment of facsimile transmission, that is to say the transmission of a message in the form in which it is handed in at the telegraph office, has been the goal of endeavour of administrations and companies exploiting telegraph communication for a number of years, and public services have been open for a considerable time for the transmission of facsimile pictures and messages.

By *wire* telegraphy the problem of picture and facsimile working can be said to be solved to a large extent, but the problem of providing high speed facsimile services on long distance short wave circuits has not yet been solved. Modern facsimile transmitting or receiving apparatus does not impose an upper speed limit on such a circuit, but the intervening space between the transmitter and receiver does impose a very definite limit on the speed at which facsimile messages can be faithfully reproduced. In other words, high modulation frequencies are not possible on such circuits. This limitation is due to the fact that although one pulse or dot may be signalled, the waves so radiated will be reflected from the Heaviside layer a number of times, and the distances traversed by the various rays will be unequal. At the receiver end a number of overlapping pulses or dots will be received, and the delay between the first and last dot may be more than 0·01 sec.

For example, during tests on 60 metre waves between Somerton and Chelmsford, a distance of about 144 miles, the maximum time interval observed between the first and last echo was about 0·005 sec. during the day and 0·0143 sec. during the night. On transatlantic circuits using waves of about 22 metres, the interval between the first and last impulse varies from about 0·001 sec., to 0·01 sec.

In short-wave radio-telegraphy the ear and brain do not take notice of the relatively short intervals between these echoes, and as a result telephony, that is to say high modulation frequencies, can be employed without apparent distortion (assuming the terminal apparatus to be free from distortion). The facsimile machine is, however, really a photographic oscillograph, and a very clear record of the mutilation is shown by a series of multiple images of a single transmitted impulse. Therefore, in order to achieve successful transmission of facsimile, the speed of working has to be adjusted to the prevailing circuit conditions, *i.e.*, it has to be reduced to such a value that the overlapping impulses merge into a single line and the apparent distortion is thus made negligible.

The following table gives some figures of the speeds of working found to be commercially practicable under transatlantic conditions using beam aerials. The wavelength employed was 22 metres, and the distance 3,000 miles :—

Linear velocity of exploring spot.	Period.	Typewriting in 5-letter words per minute.
In. per sec. 3·61	Twilight and night	20
7·22	Daytime	40
10 83	Abnormal daytime conditions	60

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For those not familiar with the subject, it may be mentioned that 10 typewritten words occupy, with the standard lettering, a space of approximately 1 sq. in.

Actually the facsimile terminal equipment is capable of reproducing messages at linear exploring spot velocities as high as 120 in. per sec., corresponding to a speed of 66½ sq. in. per min., or a typewriting speed of approximately 665 words per min.

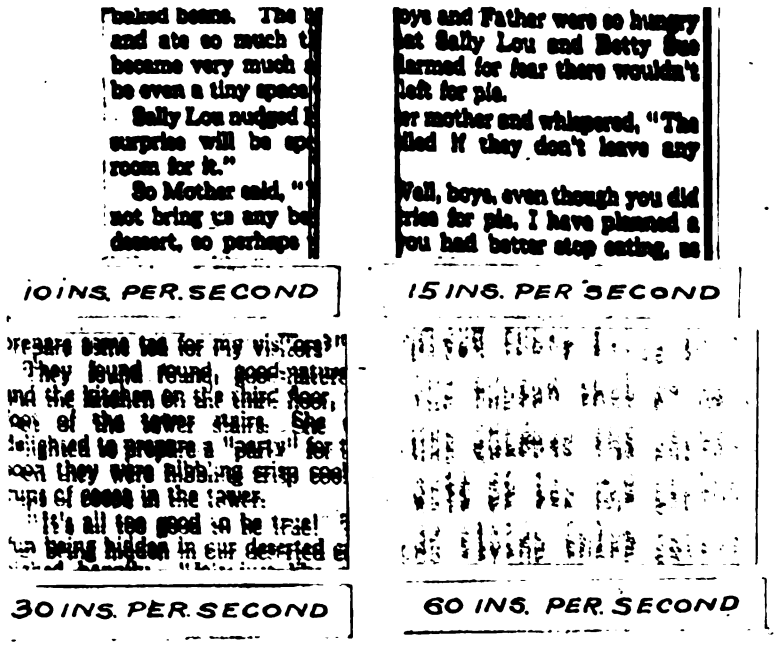

FIG. 2.

Fig. 2 shows the effect of attempting to transmit facsimile at high speeds. A linear spot velocity of 10 or 11 in. per sec. is the speed I have cited as being the maximum on 22 metre waves on the transatlantic circuit, under abnormally favourable conditions. At higher speeds, say 15 in. per sec., distortion begins to show up, at 30 in. per sec. it is very bad, and at 60 in. per sec., or the equivalent telegraph speed of 330 words per min., the script is unreadable.

The problem of increasing the speed of facsimile transmission is being attacked by increasing the directivity of the aerial polar diagram in the vertical plane, so as to limit the solid angle of radiation of aerial systems. Thus it is hoped to limit as much as possible the number of rays passing between transmitting and receiving aerials. Furthermore, present theories suggest that on shorter waves, for example 16 metres, better results are to be expected than heretofore, and that the maximum echo lag on a 16 metre transmission to New York is likely to be only one-fifth of

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that on 22 metres. Results of tests to be carried out on 16 metres between England and Montreal were therefore awaited with keen interest. They have just come to hand and, happily, confirm the accuracy of the prognostication.

Reverting to an earlier remark, that the facsimile machine is really a sort of photographic oscillograph, it is interesting to observe that experiments with this apparatus have given unexpected impetus to the study of short wave propagation phenomena. From the results of tests, accurate data have been supplied upon which scientists have been able to build up their theories.

Developments in Point-to-Point Services and Practice.

The use of directive aerial systems both for transmission and reception on short waves has now become an accepted principle and established practice, and a number of different shapes and forms have emerged. Endeavours are now being made to improve their directive efficiency and to control their polar diagrams both in the horizontal and vertical planes, either by varying the form and disposition of the aerial wires and reflectors, or by inclining them from the vertical or horizontal, as the case may be.

In the interests of economy, the design of a directive aerial becomes a compromise based on the probable earning capacity of the proposed circuit. Economy has been sought in feeder and distribution system costs by using twin open-wire feeders, as opposed to concentric copper tubes. So far as the transmitting station is concerned, radio engineers are perhaps not yet agreed. On the one hand concentric tube feeders are reliable in service and certain in behaviour and efficiency, but their cost is high. On the other hand, open-wire feeders are cheap, but their behaviour as non-radiators is more difficult to control, and consequently their efficiency is more variable.

At the receiving station the concentric-tube feeder has the valuable advantage of perfect screening, or absence of pick-up from local sources of interference.

With competing services arising in all directions, the natural tendency is to reduce initial costs and maintenance charges wherever possible, and recent practice has been to group a large number of transmitters or receivers, as the case may be, on the same site, and to locate such sites at a moderate distance from a central office situated at a traffic centre.

A further development is to situate both transmitter and receiver on the same site where possible, of course without sacrificing the advantages of duplex working. This has been done at a number of stations, and is contemplated in a number of cases where new stations are to be erected. The principle employed in this achievement is quite simple, *i.e.*, the receiving aerial is placed in the direction of zero radiation from a beam transmitting aerial or vice versa. In either case a small difference of frequency is quite sufficient to avoid interference between transmitter and receiver.

The type of cyclic fading known to radio receiving engineers as selective fading is being attacked both at the transmitting and receiving ends of the circuit by the so-called diversity methods. Modulating the transmitter output at a tone frequency yields a diverse frequency effect which has been found to improve considerably the general level of signal strength, with the result that since modulation has been

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introduced there has been a very noticeable increase in the average effective speed of communication on short waves, accompanied by an increase in the average daily number of hours of recordable signals. At the receiving end diversity reception, or simultaneous reception of signals on separate or spaced receiving aerials, is also found to be very effective. Large area directional aerials, both for transmitting and receiving, have a similar effect.

Modulation is not favoured in some quarters on the ground that it occupies a wider band of frequencies than C.W., but it has the advantage that it improves the reception of distant stations where for economical reasons or lack of space, as on board ship, it is not practicable to employ beam or diversity aerials.

Diversity, *i.e.*, spaced aerials, are practicable for large receiving stations where a number of circuits and, therefore, receivers are concentrated at one place and can be jointly connected to the same aerials. Generally it may be said that each method has its advantages according to circumstances.

In order to cope with the high signalling speeds required for facsimile keying, for example, and to effect economy in land-line charges between the central radio office and the transmitter, improvements are continually being made in keying methods, and it is becoming the established practice to employ tone sending over the intervening land lines and cables.

As regards installation design, the present tendency is to take 3-phase power from the supply mains and to eliminate all running machinery and batteries by using static transformers and rectifiers to generate all plate, grid and filament supplies.

Much work is also being done on the design of reliable frequency meters for station use, and also in the design of commercial apparatus for the rapid and accurate measurement of incoming waves, based on multivibrator or other fundamental methods.

Anyone acquainted with short wave working or even with the Berne list of frequencies must have observed that the separation between station allocations is becoming smaller and smaller and that the need for frequency constancy is becoming more evident every day. The tendency is therefore not only for the controlling administrations and governments but also for the exploiting companies to set up monitoring stations whereat they can make rapid and accurate measurements of the outgoing frequencies of stations under their control or with which they are in communication, and also of interfering stations. In some quarters a further step has been made and field strength measuring sets are being used to advise or give warning as time progresses of a change of frequency on any particular channel.

(*To be Continued.*)

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MARCONI UNDULATOR TYPE U.G.6a

The following article describes a type of undulator which has proved of great service on high speed, heavy traffic circuits. In this type a method of feeding the paper slip is arranged in such a manner that no cessation of signal recording takes place between the finish of one slip and the insertion of another.

WHEN using Undulators for recording morse signals, at very high speeds, on continuous or heavy traffic circuits and particularly when the marks have to be of considerable size for " running slip " transcription, the amount of slip used and, consequently, the frequency with which rolls of slip have to be inserted in the instrument become large.

The delay caused by this operation and the transmitter time involved by " breaks " are of serious consequence on important circuits ; on simplex working, much more loss of capacity may occur.

In Wheatstone Recorders this difficulty is eliminated by the use of double slip drawers but the same arrangement cannot be applied to Undulators by reason of the fact that the writing point never leaves the paper and it is impossible to enter a fresh slip directly under the syphon point as would be necessary every other time the change was made.

Various methods of gumming on the end of a new roll have precluded the use of drawers in the base of the instrument.

A method for overcoming the difficulty is described for application to Undulators but it also has advantages when used on Wheatstone Recorders.

Two drawers are arranged in the base of the instrument one immediately above the other in such a way that, when the lower one is pulled out, the upper one falls into the lower position. Means are provided to prevent the top drawer being pulled out also and to dropping suddenly.

The slip is normally used from the bottom drawer and, therefore, the fresh roll is inserted in the top position ; the new end of slip will consequently always be on the same side of the running slip and can be arranged to go underneath it.

The writing platform is a roller and from there to the pulling roller extends a flat platform or guide. It is only necessary to insert the new end of slip under the writing roller whereupon it is carried round and along the guide by the pressure of the running slip until it reaches the pulling roller which then proceeds to pull both slips.

When the inside end of a roll of slip is gummed to a cardboard centre, it is necessary to break the old slip before it pulls up taut. This can be done by hand or,

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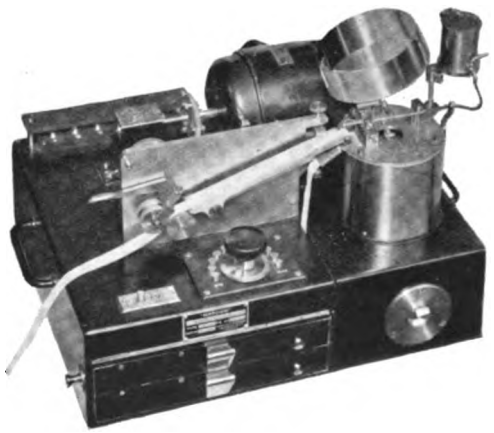
preferably, by a small guillotine in each drawer so arranged to exert no drag on the slip.

The loose end of the old roll having passed over the writing roller, the signals are continued, without interruption on the new slip. The bottom drawer is then withdrawn, reloaded and inserted in the top position ready for the next change.

Figs 1, 2, and 3, show how the idea has been incorporated in the U.G.6a Undulator.

Two cast metal drawers 1, mounted in the cast metal base 2, each carry a tape wheel 3, tape guard 4, pulleys 5 and 6 for guiding the tape and a guillotine 7 operated by a push-rod 8 and button 9.



The base is slotted at an angle to the vertical where the slip is led through so that the slip from the bottom drawer to the guide roller 10 is clear of the top drawer.

From the guide roller the slip passes through the guide chute 11 over the writing roller 12 and along the guide trough 13 to the pulling wheel 14.

The drawer, containing a new roll of slip, is inserted in the top position ; the spring catch 15 engages with the notch 16 in the drawer and prevents it being inadvertently withdrawn.

When the slip in the lower drawer is nearing exhaustion that from the top drawer is fed over the roller 10 through the chute 11 until it engages between the writing roller 12 and the running slip which being in tension pulls the new slip over and along to the guide trough 13 where it engages with the pulling roller 14.

The slip in the lower drawer is now cut by pressing the button 9 which releases the trigger 17 of the guillotine 7. The action of the guillotine is so rapid that no drag is put on the slip and no distortion of the recorded signal occurs.

When the end of the old slip passes over the writing roller 12 recording continues without interruption on the new slip and no signal is lost whatever the speed of working.

Now, in order to replenish the roll in the lower drawer it is pulled out ; although the upper drawer rests on the lower it is prevented from being withdrawn also by the catch 15 engaging in the notch 16.

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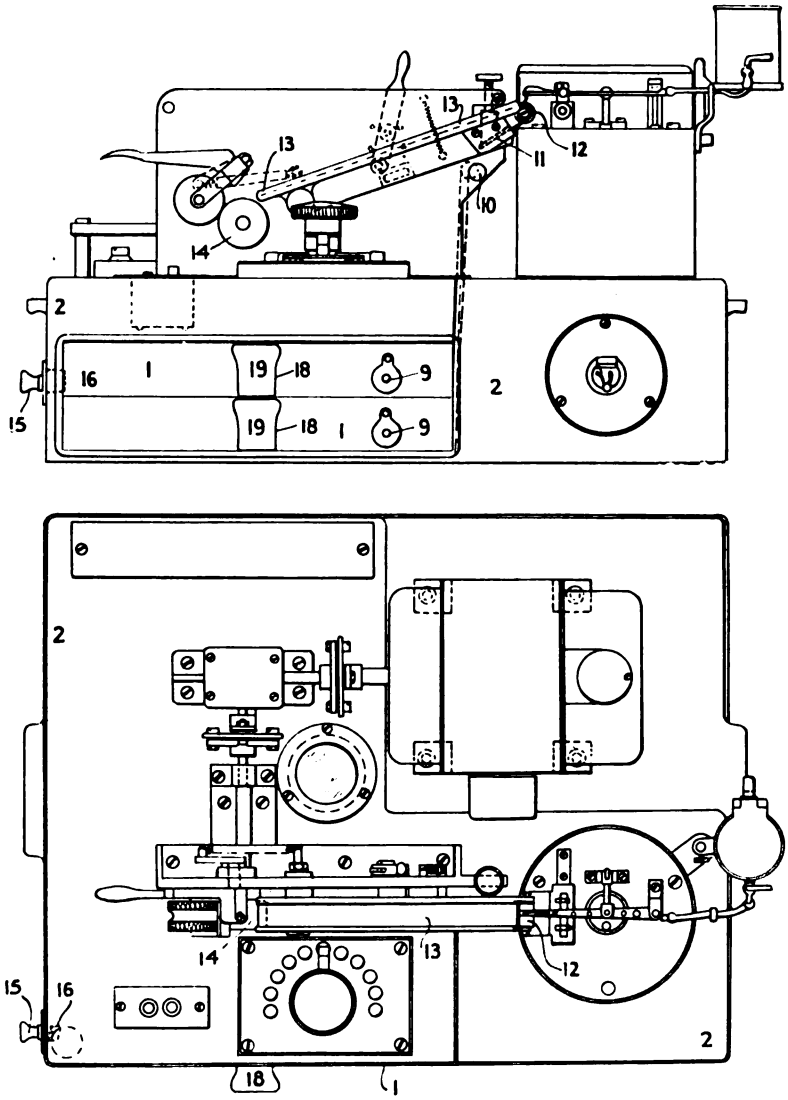
The top drawer falls into the lower position on the withdrawal of the empty drawer ; the handles 18 of the drawers are so shaped that the back of the lower drawer slides over the inclined underside 19 of the upper handle and so prevents the



sudden fall of the drawer and any drag on the tape. A spring loaded arm 20 on the guide roller 5 in the drawer also militates against this.

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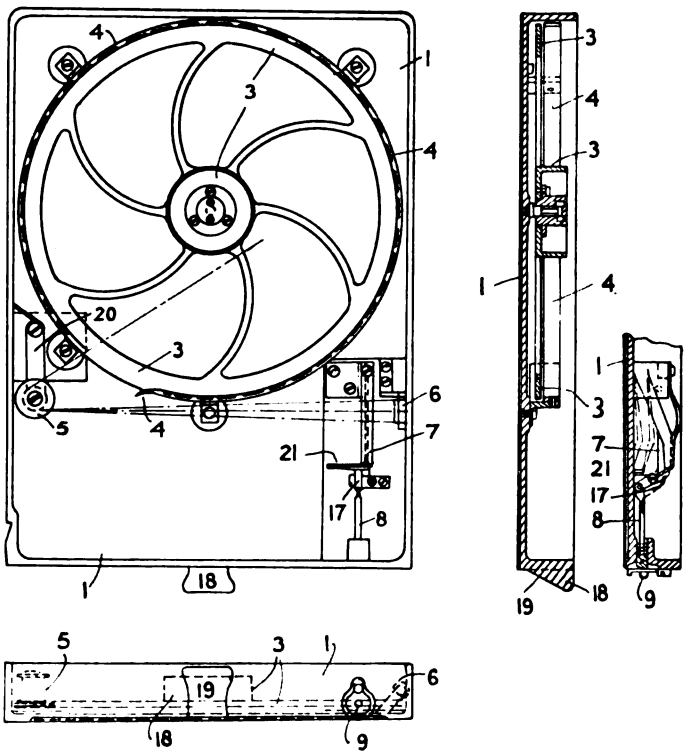
After refilling the empty drawer the guillotine is reset by lifting the bar 21 and the drawer is inserted in the top position ready for the next change.

Should the guillotine in the top drawer be operated in error, the top drawer can be withdrawn, by releasing the spring catch 15, and the threading procedure performed again.



Experience may show that the guillotine action should be made dependent on the withdrawal of the drawer.

With different types of recorded signal it may also be found an advantage to cut the slip at an angle in which case the guillotine knives may be inclined in the horizontal plane.

The Recording part of the apparatus is of the moving coil type, development having been along the lines of a robust instrument capable of withstanding the wear and tear of heavy duty rather than that of extreme sensitivity ; while signals up to 320 w.p.m. can be recorded with the large amplitude required for " running slip "

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transcription it is necessary in general to operate the recorder from a valve or mechanical relay.

The desirability of obtaining "square topped" recorder signals has led to the use of limit stops instead of springs for balancing the power driving the moving parts. It is found, however, that as the driving power is increased in order to obtain greater acceleration of the moving parts there is an increasing tendency for "bounce" to develop when solid stops are used, an effect which is obviously detrimental. Moreover, since it is desired to obtain as high an acceleration of the moving parts as possible, the employment of damping means to reduce the effect of this bounce, is inadvisable and it is found that stops of self restoring material, such as rubber, or even of felt, are not satisfactory.

Accordingly a limit stop device is fitted which is called a friction or inertia stop. The adjustable stops are mounted in a U-shaped carrier which is also capable of an adjustable amount of lateral movement between secondary stops; this movement is frictionally restricted by an adjustable flat spring pressing the U-shaped carrier against the base member.

For any given power driving the moving parts the deceleration can be arranged so that there is no "bounce" and this is accomplished without reducing the acceleration when the moving parts are starting from rest. In practice it is found that the amount of movement required between the secondary stops is very small, about one-tenth of that between the main stops.

The moving coils are provided with two windings of 1,000 turns and 1,000 ohms each suitable for operation in the anode circuits of mark and space valves of a double cut-off bridge. The current required for high speed under these conditions is 30 m.a.'s mark and space.

When connected in the local circuit of a relay it is an advantage to connect a shunted condenser in series with the Undulator coils, suitable values being 2 mfds. shunted by such a resistance as will give a standing current of 15 m.a's.

J. A. SMALE.

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100 K.W. VALVE

TYPE C.A.T.10

The introduction of the super-power type of broadcast transmitter such as that erected at Rasin, near Warsaw, and described in the last issue of THE MARCONI REVIEW, *has provided the opportunity needed to introduce into service the* 100 *k.w. type of water-cooled valve which is described below.*

A PHOTOGRAPH of the Type C.A.T.10 Valve is shown in Fig. 1, with a meter rule beside it to give some idea of its dimensions. The valve is more or less orthodox in design, having a glass envelope at the top, to which are mounted the filament and grid structures and a cylindrical metal anode at the bottom. Water cooling is used on this anode ; the valve filament leads also are cooled by contact with a flow of water.

The overall dimensions of the valve are 1080 × 170 millimeters approximately, and the weight of the valve alone is 18 lbs., the water jacket and water weighing another 14 lbs.

The electrical data are approximately as follows :—

Filament volts, 30.
Filament current, 225 amps.
Amplification factor, 45 } Taken about
Impedance, 3,500 ohms. } E_A 12000 and E_G 0.
Anode volts, 10,000—15,000.
Continuous anode dissipation, 50 k.w.

The normal operating conditions are given below :—

Telegraphy : Input, 8 amperes mean anode current at 10,000/15,000 anode volts D.C.

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Telephony : High Power modulation—Input, 5 amperes mean anode current at 12,000 anode volts D.C.

Low Power modulation—Input, 5 amperes mean anode current at 12,000/15,000 anode volts D.C.

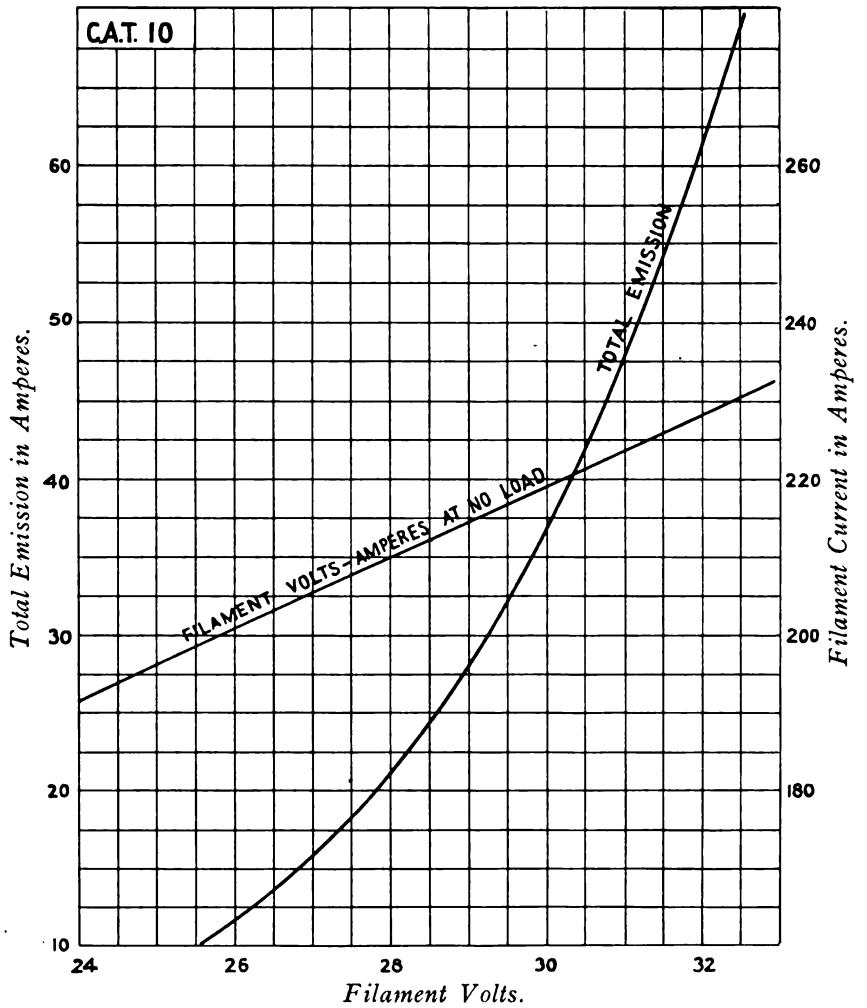

FIG. 2.

Two curves are given in Figs. 2 and 3, the first giving the relation between the filament potential and filament current, and the filament potential and total emission; and the second giving the relation between the plate voltage and the total space current.

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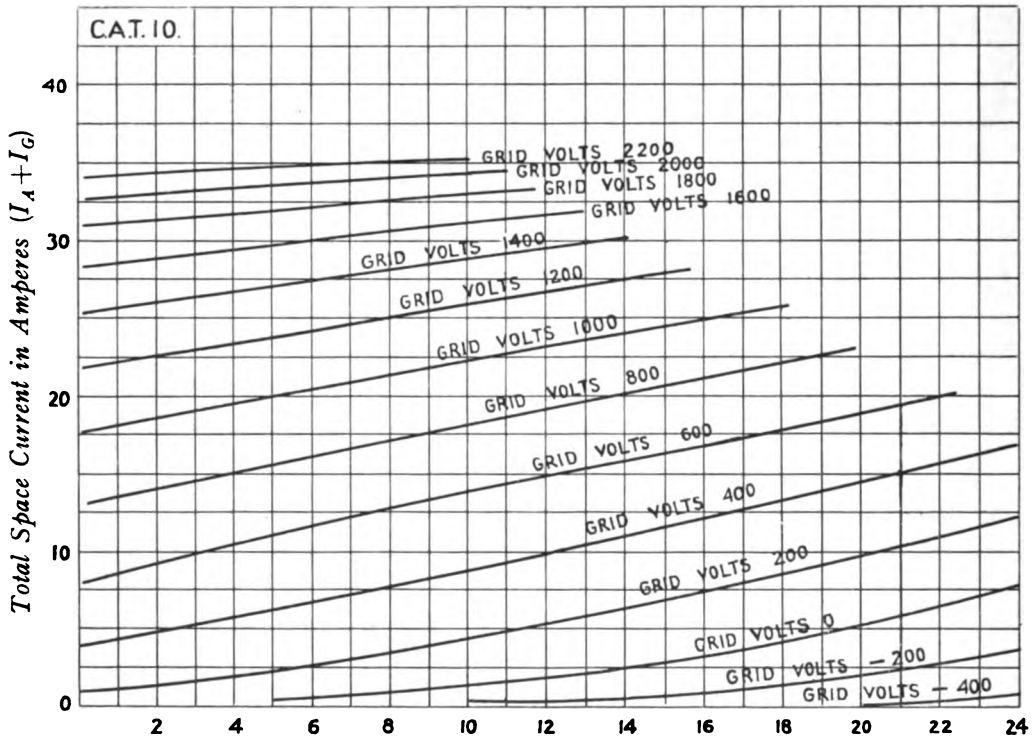

Taken at E_F to give 38 *Amperes Total Emission.*

FIG. 3.

As has been mentioned in the article referred to above, on the Warsaw transmitter the P.B.3 set employed at this station uses 8 C.A.T.10 valves in the power amplifier stage, at an anode voltage of 12,000 with a possibility of this being reduced to 6 valves operating at a voltage of 15,000. The response of these valves was found to be linear up to 80 per cent. modulation.

W. J. PICKEN.

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MARCONI NEWS AND NOTES

WIRELESS DEVELOPMENT IN 1930

IMPORTANT advances have been made during 1930 in the development of each of the three main sections of modern wireless: (1) broadcasting; (2) telegraphy and telephony, and (3) special services, such as marine, aeronautical, and military.

In broadcasting, considerable improvements have been made in technique, necessitating in some cases radical departures from previous designs.

One of the most notable changes is the tendency to replace small relay stations working from the main broadcasting transmitters by high-power regional stations which are capable of producing substantially constant field intensities over large areas. Stations of this kind supplied by the Marconi Company during the year include Spanga (Sweden), Iceland and Warsaw.

On account of the high power of these stations considerable precautions are required to prevent unnecessary mutual interference. This avoidable interference may be divided into two types;

(A) Interference caused by the departure of the station from its intended wavelength;

(B) Interference caused by the radiation of harmonics of the fundamental wavelength.

Interference due to the first of these causes has been minimised by the provision of suitable constant frequency drives for the broadcast transmitters. These drives may be either of the valve, tuning fork, or quartz crystal type according to the conditions under which they work, but all are capable of keeping the main transmitter on its allotted wavelength to a high degree of accuracy.

The provision of harmonic attenuating filters has done much to eliminate the radiation of unwanted harmonics.

Modern Transmitter Design.

A good example of modern transmitter design is to be found in the equipment of the new broadcasting station which has been erected by the Marconi Company at Rasin, near Warsaw. The transmitter is of the power amplifier type, and possesses an aerial carrier energy of approximately 120 kilowatts with 80 per cent. modulation.

Broadcast receivers are necessarily becoming more selective, and nearly all high-class receivers incorporate some form of band selection. Other advances are the development of "power grid detection," and improved methods of low frequency

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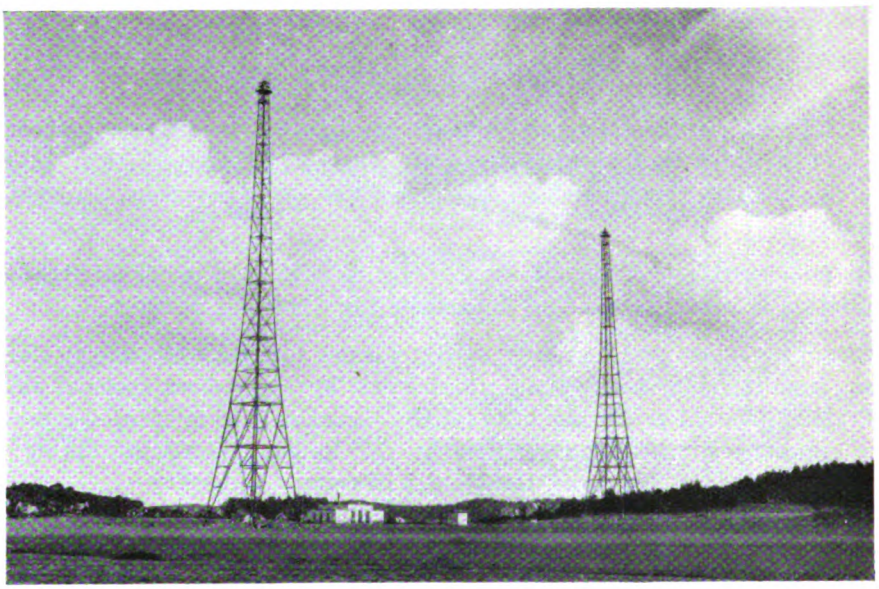

Marconi high-power broadcasting station at Spanga, Sweden.

amplification rendered possible by the advance in A.C. and D.C. valve construction, and extensive research work on the design of audio frequency transformers.

The development of broadcast transmitters has created inevitably a demand for studio equipment and landline linking apparatus of a higher degree of perfection. A growing proportion of the total programme material is transmitted from cultural centres by landline and radiated from comparatively distant transmitters, and it is necessary to ensure that these programmes can be given with a fidelity of transmission comparable to that obtained on local circuits. Studio equipment and landline linking apparatus have therefore been developed to meet this demand.

Facsimile Transmission.

The art of signal transmission by facsimile methods is less advanced than the transmission of messages by telephony or telegraphy, but in the past year considerable progress has been made in increasing the speed of long distance facsimile transmission and reception. Marconi apparatus for this purpose is being installed for communication between England and Canada, and England and South Africa.

The most serious obstacles in the way of an efficient world wide system of facsimile communication lie in the fact that the conditioning factors of short wave propagation involve echo and other effects which are deleterious to such trans-

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mission. Research is being carried out on the subject in order to improve conditions of transmission and reception not only of facsimile work but of all short wave traffic.

A recent development is the production of a practical portable facsimile apparatus which can be used for the transmission and reception of simple diagrams, charts, and so on, between aircraft and other mobile stations and their bases.

Changes in Wireless at Sea.

Notable changes have taken place in marine wireless communication. Spark transmitters are quickly disappearing and their place is being taken by continuous wave and interrupted continuous wave sets. At the present time the installation of spark sets of greater power than 300 watts is forbidden. New types of valve transmitters have therefore been designed to meet the changed conditions. Much greater use is being made of short waves for marine communications both in the case of inter-ship and ship-to-shore telegraphy and a new development is the initiation of a commercial system of ship-to-shore telephony using short wave channels.

Apparatus for use in this connection has been installed on some of the largest transatlantic liners and is giving every satisfaction.

Wireless Stations for Arabia.

The King of Hedjaz and Nejd has signed a contract with the Marconi Company for the supply of 15 wireless stations, which will provide Arabia with a complete system of telegraphic communication.

Within the next 18 months every important centre in the joint kingdom will be linked for the first time in history by the most rapid means of communication that the world can provide—a striking development in a country where the camel messenger, travelling on the ancient caravan routes, may still be seen side by side with the modern motor car.

In addition to the fixed wireless stations which will be erected in the towns, four Marconi sets fitted in lorries are to be supplied as general mobile telegraph stations, and to enable the King to keep in constant touch with his two capitals, Mecca and Riyadh, during his many journeys into the desert.

In Mecca a powerful telephone and telegraph transmitter of the Marconi 6 kilowatt "U" Type, with a modern type receiver (Marconi R.G.19) will be installed within the sacred precincts, and as persons who are not of the Mahommedan faith are forbidden to enter the Holy City the resources of the Marconi Company are being called upon to supply a Mahommedan engineer to instal the transmitting and receiving equipment in Mecca.

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Similar stations are to be erected at Riyadh, the capital of Nejd, about 400 miles from Mecca, so that King Ibn Saud; who has palaces in both towns, will be able to talk from one to the other by means of special microphones which will be installed in the palaces.

The stations in the smaller towns will be of the Marconi X.M.C.2 Type, the transmitters having a power of 500 watts. These also will be capable of working by telephone, if required, though only telegraph services are to be inaugurated at first. They will be worked by Arab operators, and in order to facilitate working between the different stations the controls are adjusted to fixed wavelengths and interlocked, so that once the stations are erected further adjustments for wavelength will be unnecessary. By merely moving a handle into the position of " transmit " or " receive " the operator will automatically switch on the set at the correct wavelength for the service required.

This type of installation was originally developed for use by unskilled operators on whalers operating in the Antarctic, and is now in use in many parts of the world as the simplest means of providing efficient wireless telephone and telegraph services.

A British engineer will supervise the installation of the Arabian stations outside Mecca, and to provide for the maintenance of the stations after they have been erected King Ibn Saud has sent four of his subjects to England for a course of instruction in the Marconi School at Chelmsford.

The Marconi Veterans' Reunion Dinner—referred to in the last issue of the "Marconi Review."

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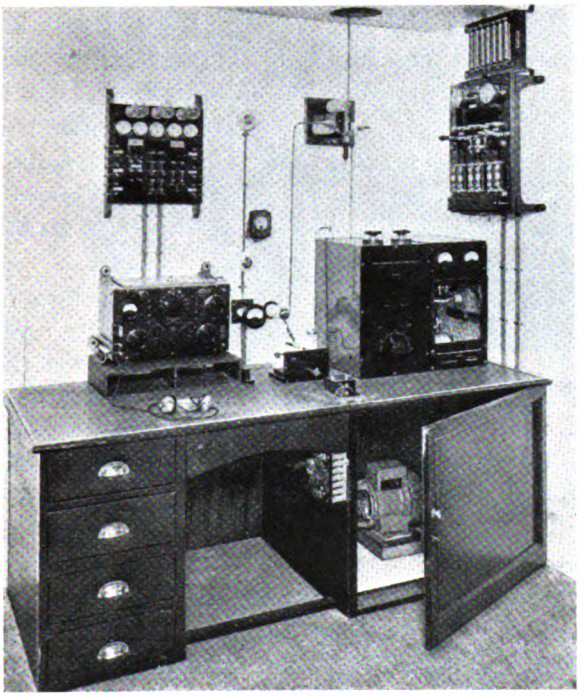
Arabia is one of the few remaining countries of the world which still retains many of the manners and customs of biblical times, and King Ibn Saud's introduction of wireless as a means of internal communication involves many striking contrasts between ancient and modern methods. All the apparatus for the stations will be transported by car or camel caravan over the desert tracks which have been in existence from time immemorial, for roads are few and the only railway in the country, that running from Transjordania to Medina, was destroyed during the war.



A modern Marconi trawler equipment.

Wireless for Trawlers.

More than forty Marconi telegraph installations have recently been ordered for trawlers in the Humber district of England. This remarkable development is due to the fact that those who are engaged in the arduous labours of the fishing industry fully appreciate the difference which a wireless installation can make to the working of the ships and to the lives of the men employed in them. It is an effective link connecting the owner, the market, and the skipper for the exchange of information to their mutual benefit. The men on the trawlers also appreciate the increased sense of security it brings to them in times of storm, and the opportunity it gives them to keep in touch with what is happening not only in the fleet to which they are attached but also in the world at large.

The specially designed Marconi trawler installations comprise a telegraph transmitter, receiver, and, usually, a Direction Finder.

The transmitter is tuned to a special wavelength for communicating with other trawlers in addition to the normal maritime wavelength for working with ships and

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coastal stations. The receiver has a comprehensive waverange which makes it possible to tune in broadcasting stations for weather reports, news bulletins, and also the high powered stations which transmit time signals, navigation and meteorological reports and other useful information. The Direction Finder has proved itself to be of great assistance in locating the exact bearing and position of other ships and land stations and thereby saving time and money on innumerable occasions.

How Radio came to America.

News comes from New York that what has been regarded for a great many years as an ordinary and somewhat homely little shack in a field near Babylon, Long Island, has been identified as the first commercial wireless station built by Marconi in the United States, and consequently as a structure of unusual interest and significance, and that it is to be preserved as an historical exhibit.

As far as it is possible to determine the facts, Marconi erected this station late in 1900 or early in 1901. This gives it a date in radio history prior to the inventor's experiments in trans-oceanic radio communications, and previous to the achievement, by which he amazed the world, of flashing the letter " S " through space across the Atlantic.

Marconi located his Long Island sending post at a point on the outskirts of Babylon, near the coast, where he could reach incoming ships while they were yet some distance from New York. He erected the tall, wooden pole, which was the mainmast of early radio ; sunk into the earth the great zinc ring that was used for a ground connection, and began on favourable days a communication with vessels as far as sixty miles at sea, at a rate of approximately ten words a minute. The station was operated by the Marconi Wireless Telegraph Company of America, which Marconi had just organised.

Discovery of the Earliest Station.

Discovery of the existence of the station and verification of the part it had played in early American radio came about partly by coincidence. The coincidence was that Captain H. J. Round, of Marconi's Wireless Telegraph Company and an early associate with Marconi, happened to mention the Babylon station while he was visiting Major E. H. Armstrong at Bayport, Long Island, last year, and expressed curiosity as to what had happened to it.

Captain Round and Major Armstrong drove over to the town. They found that it had extended towards the coast and that many houses had been built in what was open country thirty years before. A new street had been cut through from the old road, but Captain Round soon oriented himself, left the car, and glanced into the field where the shed stood.

The shed measures approximately 12 ft. by 14 ft., and in the days of its use as a radio station merely provided room for one or two operators, who lived in a

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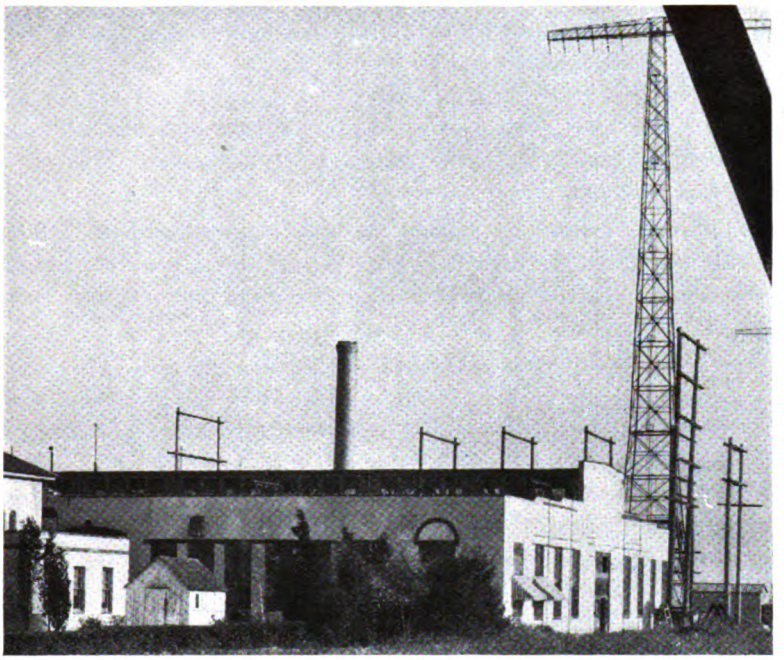

The first Marconi station in America—the hut in left foreground—contrasted with a modern wireless station.

house which no longer exists. The shed stood less than half a mile from Great South Bay, and from it on clear days a view could be obtained over the bay and Fire Island of the ocean and steamships moving down the Long Island coast toward New York.

The first experimental employment of radio in the United States was a year earlier, when Marconi supervised the installation of a temporary station on the "Forward," a tug of the Yankee Salvage Association, to report the international yacht races off Sandy Hook. A land station was built at Sea Gate, at the entrance of New York harbour, for a relay of the messages by land wire to New York. This experimental work ante-dated the Babylon station, but the latter was the first commercial post of permanent character constructed by the inventor in that country.

It was of much value to shipping companies in the days when radio was first disclosing its service to obtain reports on the probable hour of arrival of trans-atlantic vessels at New York.

Historic Equipment.

Very probably the mast was used for kindling wood. It was a well-known and accepted scientific fact in the early days of radio that an iron pole could not be

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employed as the support for an antenna (iron or steel masts are used exclusively to-day) and as a height of approximately 170 ft. was desired, the pole was spliced. The antenna was a single wire of the vertical type, reaching at only a slight angle to the ground. About the mast was laid the large zinc ring buried in the earth. The zinc circle about the pole was approximately 40 ft. in diameter. Thus the ground connection was provided.

The equipment inside the station included the transmitter, which was an induction coil that produced high voltage electrical discharges from battery current or from a dynamo. The output terminals of the induction coil were connected to a spark gap.

There was also the more elaborate receiving apparatus. In the latter, in addition to the vertically suspended antenna wire, were the coherer, a telegraphic relay, a tapper, and a Morse ink recorder. The coherer was a crude device compared with modern radio apparatus. It consisted of a glass tube with metal plugs on each end, with a quantity of loose nickel and silver filings between these plugs. When the radio wave from a transmitting station reached the antenna or receiving wire, the filings "stuck together," or cohered. This gave the device its name of "coherer." Thus the circuit of the relay was closed, and this actuated a recorder. Simultaneously, the tapper struck the coherer so as to disassociate the filings and make the coherer ready to receive the next signal. So slow a process was thus involved in the action of this apparatus that it may readily be perceived that ten words a minute was good speed, and often a slower rate was regarded as satisfactory.

Arrangements for Preservation.

After Major Armstrong had established that the shack actually was the starting place of the present-day American system of wireless communications, he purchased it and offered it to the Radio Corporation of America, the successor to the American Marconi Company.

Formal acceptance of the gift was made by David Sarnoff, President of the Radio Corporation of America. Mr. Sarnoff described the early station as one of the most valuable exhibits that could be obtained to picture the extent of radio progress. It is now erected at Rocky Point, where it offers an unusual contrast with the transmitting station that reaches all parts of the world at a rate of 150 words a minute. Engineers there pointed out that this contrast justifies the great expenditure made over the period of three decades for research and experiment in radio communications, evidencing so clearly what has been accomplished in a comparatively brief period of time.

The Babylon site was abandoned by the Marconi Company after other stations with greater range and newer equipment had been constructed on Long Island and after the American Marconi system, which had grown in size and resources, had begun conducting an extensive radio service along the coast.

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THE MARCONI REVIEW

January-February, 1931

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Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

REVIEW OF COMMERCIAL WIRELESS DEVELOPMENT (Continued)

BY C. E. RICKARD, O.B.E.

We publish below the second, and concluding part of the address delivered by Mr. C. E. Rickard, O.B.E., M.I.Mech.E., M.I.E.E., Deputy Chief Engineer of the Marconi Company, before the Institution of Electrical Engineers on November 5th, 1930, *on his election as Chairman of the Wireless Section of the Institution for the year* 1930-1931.

The first part of this article was published in THE MARCONI REVIEW *for December,* 1930.

Frequency Control.

THE need for constant carrier-frequency emission on all services becomes more and more evident every day. A step in advance from the international point of view was made at the Hague last year, when certain recommendations were made for the permissible tolerances in the various frequency bands, and administrations and manufacturers are in the main endeavouring to conform to them. The standard was not set too high for achievement in the majority of cases, but experience shows that there is a great difference between the measure of constancy a master oscillator is expected to maintain and what is experienced in actual practice. Many a constant frequency device has given promise in the laboratory of a frequency constancy of, say, 1 in 50,000 or 1 in 100,000, but in service spread over a week or a month its figure of merit has been found to be no better than, say, 1 in 10,000, or less.

It is not sufficient for a master oscillator to keep within a certain percentage of its mean frequency at any given time ; it must also not wander from its allocated frequency, that is to say the official frequency on which it is required to work. A carrier frequency which is stable, but inclined to drift, can be followed at the receiver end until it approaches a neighbouring station frequency and interference arises. On the other hand, an inherently unstable frequency, or, in other words, a wobbler or scintillator, is fatal to good telephony or broadcasting quality.

The three best known constant frequency devices in commercial use are the tuning fork, the quartz crystal, and the valve master oscillator.

Tuning Forks. The tuning fork has long been used as a sub-standard of frequency, and many of the frequency measuring sets employ tuning forks as a basis of measurement which can be checked from time to time.

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Where synchronisation has been required, as in picture transmission for example, tuning forks have been used for some time. Forks made of elinvar have been found sufficiently stable, without temperature control, to allow of the device being used with considerable success on long wave transmitters.

For the maintenance of constant frequency with forks of other materials it is indispensable to employ temperature control apparatus, capable of maintaining the fork at constant temperature to within approximately 0·1 degree F., if the best results are desired. Under these circumstances the results obtained have been remarkably good. The 10 tuning fork devices employed by the British Broadcasting Corporation to control the transmission of the relay stations on a common frequency of 1,040,000 are, I understand, still maintaining their high reputation for constancy after many months in service, and I believe their constancy can still be defined as about $\pm$ 1½ in 100,000.

The principle of tuning fork control is being extended to high frequencies, *i.e.*, short waves, where the difficulty of avoiding undesired modulation of the final frequency is more acute. This trouble has led to the use of a chain of doubling stages in preference to any other method.

Developments in the method of maintaining a fork in vibration are in the direction of minimising the effects of supply voltage fluctuation on the frequency, and the elimination of any possibility of unwanted degrees of freedom.

Quartz Oscillator. The study of the quartz oscillator has revealed the fact that if the section is suitably dimensioned the temperature co-efficient of the plate and its holder can be made positive or negative as desired. By adjusting the dimensions it is possible to change the temperature co-efficient from one sign to the other at the expense of some slight change in the frequency due to the cutting. Further, by very careful adjustment of the dimensions it has been found possible to produce quartz oscillators of a given frequency the temperature co-efficient of which is of the order $\pm$ 2 or 3 parts in 1 million per degree C. change of temperature.

Unfortunately, whilst this result has been obtained on crystals of a frequency as high as 250,000, at still higher frequencies the crystal itself is thin, and its behaviour becomes spasmodic.

With crystals of ideal dimensions laboratory tests have shown that changes of valve voltages of the order of $\pm$ 5 per cent. have produced such small frequency changes that to make an absolute measurement is a matter of great difficulty.

Some measurements of three quartz-driven stations working on a common wave of about 1,318 kilocycles per sec. have shown that between A and B stations there was a frequency change of from 0 to 16 cycles per sec., whereas between A and C stations there was a frequency change up to 80 cycles per sec. These changes are therefore of the order of 1 to 5 in 100,000.

Valve Master Oscillators. With this type of constant frequency device the main difficulties to be overcome are the variations of frequency due to dimensional changes of the oscillatory circuit, that is to say condenser and inductance, due mainly to changes of temperature or flow of the material, and changes of supply voltages to the valve filament, anode and grid. Several circuits are known which take care of

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the valve problem, but the attainment of stability of the oscillation constant of the condenser inductance circuit over long period, even when maintained at constant temperature, is a problem of considerable difficulty.

Mr. C. S. Franklin has made a special study of short wave constant frequency devices and has developed one in which the condenser inductance circuit is of particularly robust construction, of special materials, and in which the principle of automatic correction for temperature variation is applied.

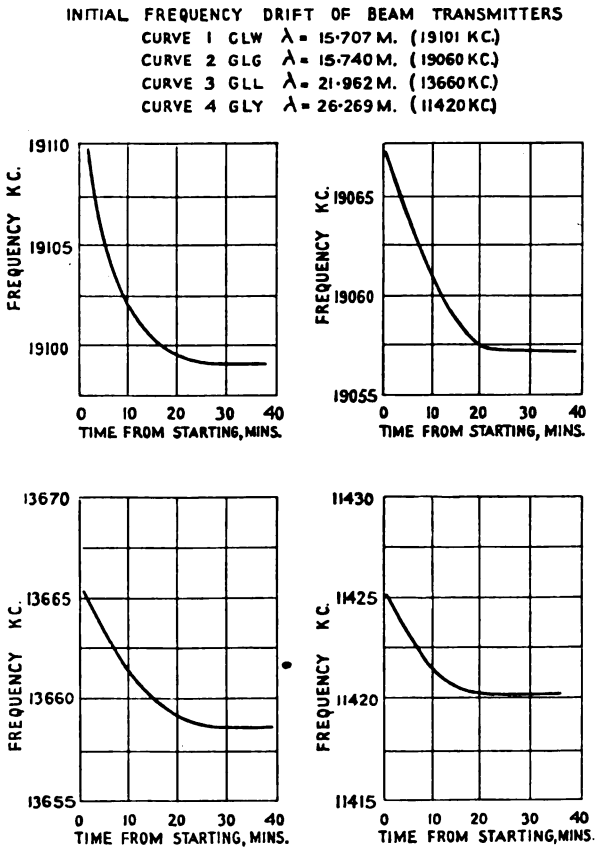

FIG. 2.

At this point one must distinguish between the transmitter fitted with an ordinary valve drive and the type developed by Mr. Franklin, in which the constant frequency device is composed of a number of stages, including doublers, on exactly similar lines to the quartz crystal constant frequency device, so much so that in the new device a crystal may be inserted in the circuit if so desired.

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Taking ordinary valve drives first, much can be done in the interests of frequency stability by eliminating vibration, by using accumulators for filament lighting and employing a very constant H.T. supply to the master oscillator, together with the use of as low a power as possible and an isolator stage, and by careful screening of the master oscillator and isolator stages from the rest of the circuits. To this must be added the use of inductances and condensers of robust and inflexible design, the whole maintained at as even a temperature as possible. Such was the design of the beam station transmitters, the note of which was for a long time recognised as the most constant of those in regular service.

Valve drives of the normal type suffer, however, from drift, due to starting-up conditions (principally temperature variations). The short wave marine transmitter with or without a master oscillator is a bad offender in this respect, and when such stations are started up they may drift over 10 to 50 kilocycles per sec. during the first half-hour. This constitutes a great difficulty in short wave ship communication because, as a rule, the normal ship station *does not require to work* for more than half an hour at a time.

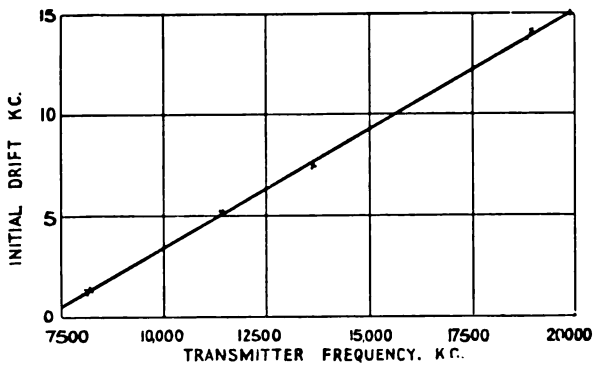

FIG. 3.

Where special precautions are taken, as in the beam stations, the drift on starting-up may still be as much as 10 kilocycles per sec. in 20,000 or 1 in 10,000 if the transmitter is left unattended.

Some observations made by Mr. Pannett at the Dorchester station illustrate the effect of changes of filament and anode voltages and of temperature on the frequency on well designed valve-driven transmitters.

Fig. 2 shows the effect of temperature during starting-up conditions, no adjustments being made during test to correct the frequency.

Fig. 3 shows the drift observed on a number of different frequencies. It is a straight line and shows that initial drift is roughly proportional to frequency.

Fig. 4 shows the effect of varying the anode voltage on three different transmitters.

Fig. 5 shows the initial drift on a transmitter compared with the rise of temperature measured in different parts of the master oscillator chamber.

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Fig. 6 shows the effect on the frequency of varying the filament voltage. The vagaries of these curves vary with individual valves.

Normally the engineer on watch makes the necessary adjustments during the starting-up period by checking against his standard wavemeter, and the outgoing frequency is kept within the prescribed limits. Obviously the provision of a good wavemeter or frequency measuring device is an absolute necessity in normal valve-driven stations, whether long or short wave, and the reputation of such stations depends largely on the reliability and precision of the wavemeter and the attention of the engineer-in-charge.

In the new constant frequency device two oscillator valves are used in combination and the principle of differential expansion between the insulating material constituting the former on which the coil is wound, and a brass rod carrying a small condenser of the vernier type, is made to compensate for changes in the L and C values of the oscillating circuit due to expansion or contraction. With this apparatus temperature control of the chamber in which the device is contained becomes unnecessary.

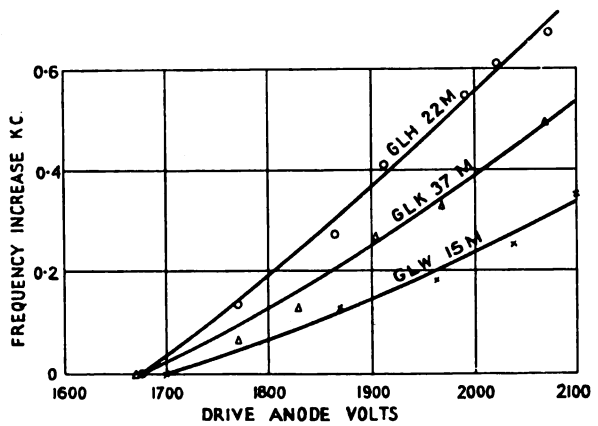

FIG. 4.

Adjustment of the compensator is made to correspond to the centre of the scale, but it is found to be accurate over the whole scale of the standard instrument, which in one of its forms covers a 2,000 cycle range on a 15 m. wave.

The curves in Fig. 7 show the variation of frequency, with variation of high tension supply to the two master oscillator valves. It will be noted that a variation of about 2½ per cent. in H.T. voltage corresponds to a change of 100 cycles in 11 190,000, or about 1 in 100,000. The four curves show the behaviour with various combinations of valves of the P 610 and L 610 types.

Fig. 8 shows the effect of varying the filament voltage. As might be expected the lack of absolute uniformity among valve filaments shows up here, and the curves have divers shapes. A variation of 0·5 volt in the standard voltage applied to the 6 volt filament in no case makes a change greater than 100 cycles, or 1 in 100,000.

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Fig. 9 shows the change in frequency of such an oscillator working on 15,050 kilocycles per sec., or approximately 2c m. waves, when heated in a cabinet from the room temperature of 21°C. up to 46° C., and then allowed to cool again to a room temperature of 18° C.

During the first hour's heating the temperature of the cabinet rose rapidly to its final temperature 46° C., yet there was no observed change in frequency of the oscillator as checked against a standard frequency meter. This is an important point as it shows that the frequency of the oscillator is not affected by sudden changes of temperature produced by draughts of air.

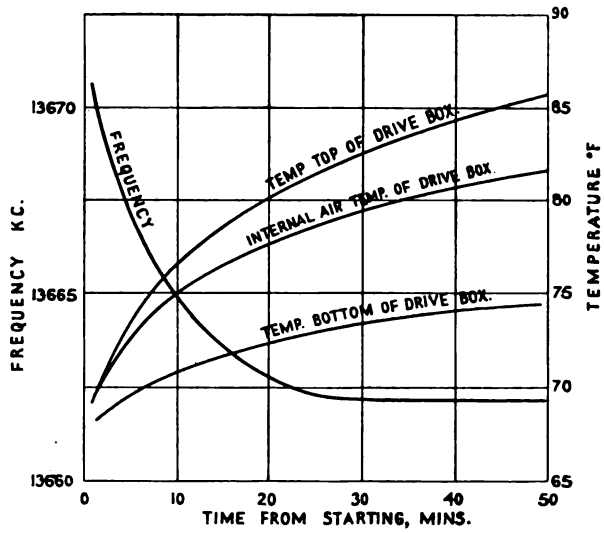

FIG. 5.

After about 5 hours' heating a small drift of approximately 25c cycles per sec. was noticed ; this, however, did not change after a further 2 hours' heating. This change indicates that the oscillator is slightly over-compensated, and is noticeable only when the heat has penetrated right into the materials, especially into the insulating material, which has a low thermal conductivity.

After 7 hours the heaters were switched off and the oscillator cooled down slowly, overnight, in the cabinet. A measurement of the frequency made the next morning indicated no change. During the heating the temperature of the frequency meter rose 1° C., and a correction of minus 100 cycles per degree C. rise has to be made to any observed drift. As the scale of the frequency meter will only permit reading to 250 cycle divisions on its vernier, there is thus a probable error of ± 250 cycles in the actual observation of the oscillator drift measurement over 25 degrees. Thus the drift of the oscillator was 150 ± 250 cycles for a temperature rise of 25° C., or, in other words, + 6 ± 10/15 050,000 cycles per degree C., roughly about 1 in 1,000,000.

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Broadcasting.

One of the outstanding events in broadcasting transmitter technique during the past year or so has been the tendency in Europe to adopt high-power transmitters. At international conferences a year and a half ago at Prague and last year at the Hague, arguments were put forward recommending the restriction of antenna power to about 100 kw.

The political and cultural value of broadcasting is so recognised among the nations that notwithstanding the splendid and successful efforts of the Union International de Radiophonie in adjusting to the best advantage the wavelengths, or should I say frequencies available for broadcasting, the total number of carrier frequencies allocated appears under present circumstances to be insufficient for the peculiar needs of

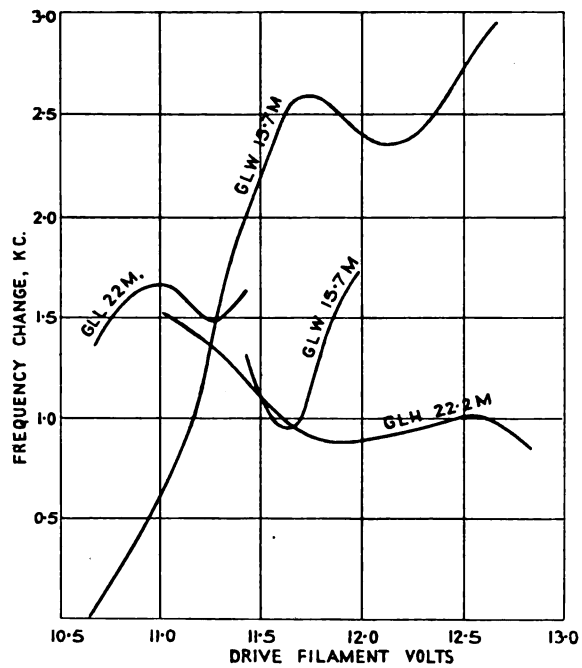

FIG. 6.

our densely populated Continent with its great diversity of tongues. As a result some of the nations are being obliged to make shift with a minimum number of exclusive frequencies and to increase the power and radius of their stations.

Notable high-power stations already working in Europe with C.C.I.R. aerial rating of 60 kw. or more are Spanga, Rome, Oslo and Moscow, and Prague and Warsaw are in course of construction.

High-power transmitting valves have made their commercial appearance in the design of broadcasting stations and perhaps some particulars of the new Marconi

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100 kw. valve, which I understand have not yet been published, will be of general interest. The valve, known as the C.A.T.10, which is rated at 100 kw. input to the anodes on a telegraph load, stands about 3 ft. 6 in. high, its overall dimensions being 108 × 17 cm. The filament current is 225 amperes at 30 volts, and the anode voltage 10,000 to 15,000, the continuous anode dissipation being 50 kw. At 12,000 volts to the anode with zero grid bias the amplification factor is 45 and the impedance 3,500 ohms.

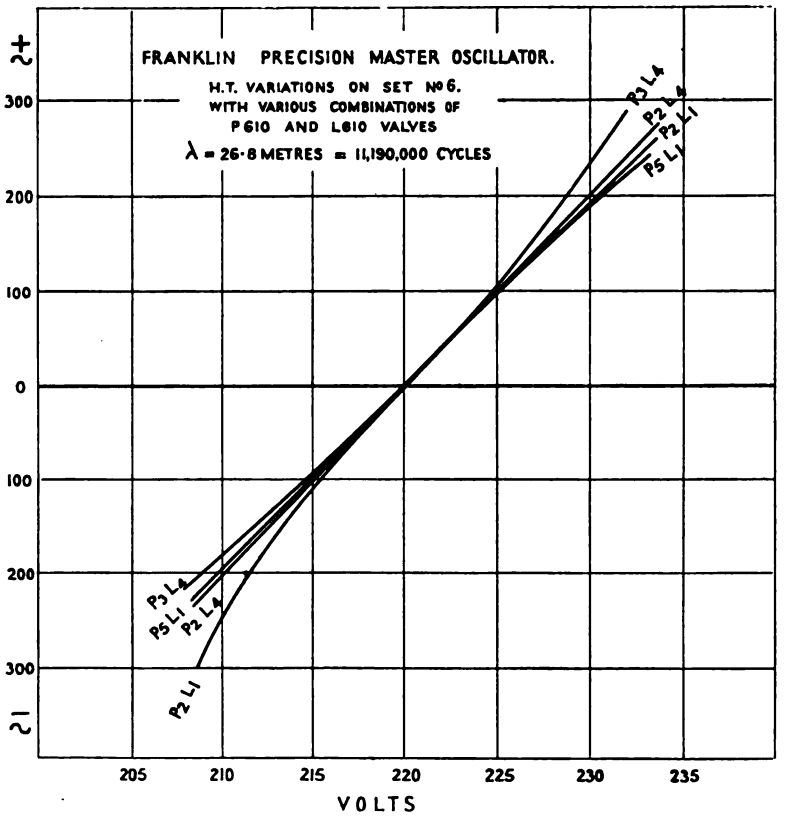

FIG. 7.

Working on long waves the normal operating conditions are :

Telegraphy .. 8 amperes at 10,000-15,000 volts.

Telephony .. High-power modulation, 5 amperes at 12,000 volts.
Low-power modulation, 5 amperes at 12,000 to 15,000 volts.

A point of interest with regard to such valves is the problem of keeping down the glass temperature at the filament seal, the difficulty being that, owing to lack of space, such heavy filament currents as are required have to pass down into the tube through conductors of minimum cross-section. In this valve the problem has been solved by water-cooling the external portion of the valve filament leads.

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In the lantern slide* the inlet and outlet tubes are clearly shown on the filament leads. Water flows down each lead to a point just above the seal, and returns again up the filament leg to the outlet tube.

Test figures for a broadcasting transmitter employing 8 of these valves, set for 80 per cent. modulation and with an anode input of 405 kw. at 12,000 volts, gave a carrier output to aerial of 120 kw., showing an efficiency of 29·6 per cent.

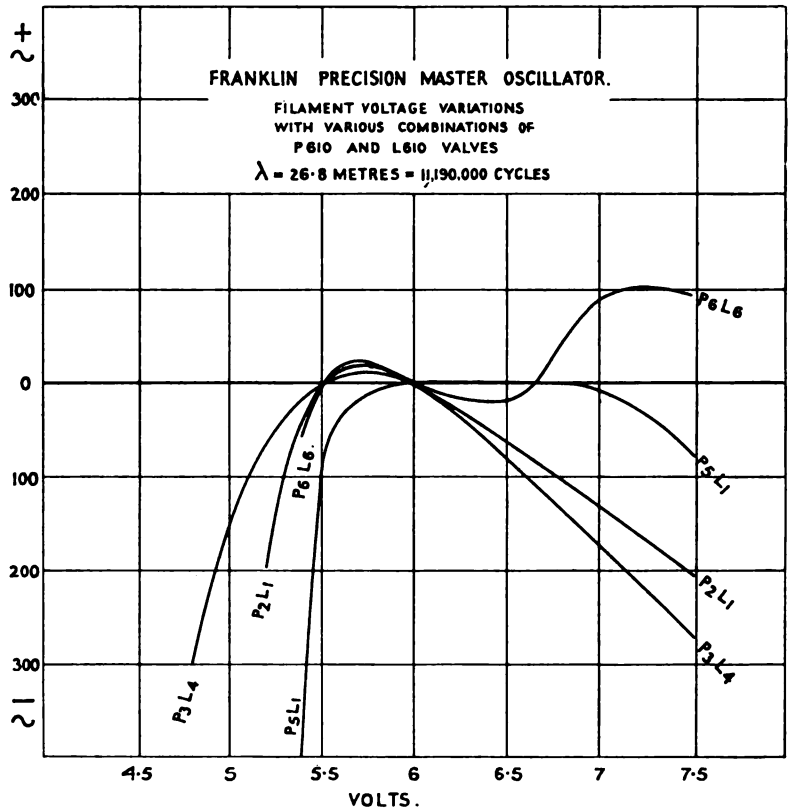

FIG. 8.

The artificial load employed for the test consisted of a morganite resistance of 465 ohms carrying 33·8 amperes.

A recent development in the design of high-power broadcast transmitting stations is the use of mercury rectifiers. Their high efficiency is an attractive feature in considering the maintenance costs of broadcasting stations, where the power to anodes runs into such figures as 400 to 600 kw. Three types of mercury rectifier are in use, viz., the mercury-vapour tube developed in America, the glass-bulb mercury-arc rectifier, and the Brown-Boveri type in steel cylinders.

* Not reproduced.

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In the transmitter test I have just mentioned the Brown-Boveri type was used and showed an overall efficiency of approximately 95 per cent.

As a point of special interest I might mention the rectifier employed at the Moscow high-power broadcasting station, which I believe is the largest in use employing glass-bulb mercury-arc rectifiers. The photographs* show the construction of the rectifier panel, which consists of 12 three-phase rectifiers, each capable of handling about 30 kw. with an efficiency of about 96 per cent. Power from the 6,500-volt 3-phase supply is taken to two transformers having star-connected outputs phased to give, in combination, a 6-phase supply to the rectifiers. The normal working load of this rectifier panel is 250 kw. at 10,000 to 12,000 volts, with 8 bulbs in service.

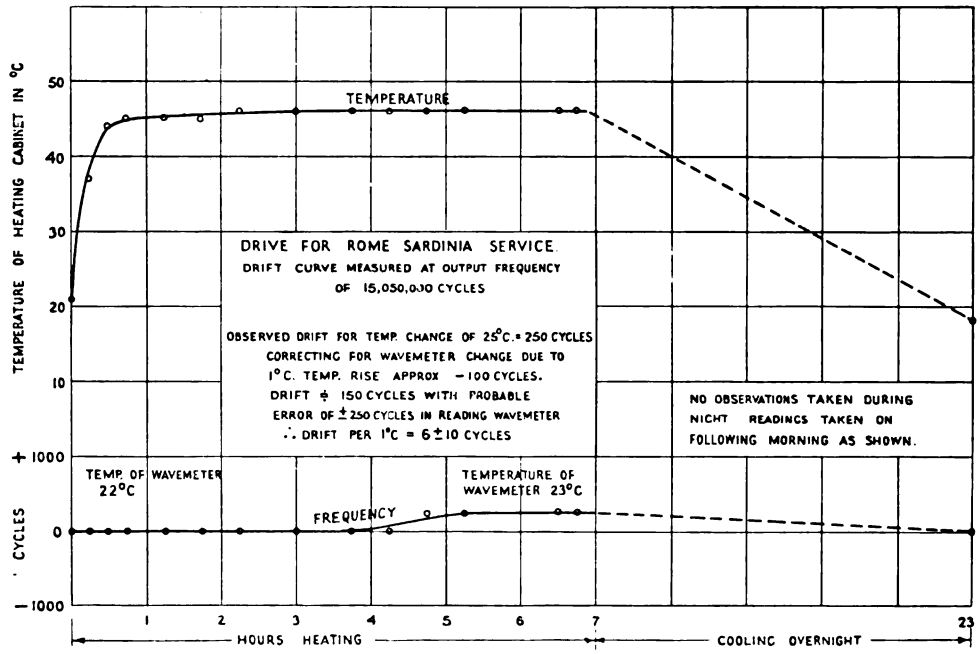

FIG. 9.

In the design of high-power transmitters, whether for broadcasting or long-wave point-to-point communications, special precautions to prevent the radiation of harmonics become more and more necessary as the power is increased.

Apart from the use of astatic coils, capacity coupling between stages, and screening to prevent interaction between units, it becomes necessary on very long-wave working, as for the new 150-kw. station at Ongar, to place the transmitter in a large room with copper screening to prevent the direct radiation of harmonics.

In large broadcasting stations it is becoming the practice to insert low-pass harmonic filters between transmitter output and aerial feeder circuit, and to screen

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all interconnections between the panels of the transmitter in earthed trunks to prevent jump over, which would stultify the action of the filter.

Land-Line and Control Equipment for Broadcasting.

Referring to the land-line and control equipment field, the present trend of development in the design of speech amplifiers consists in giving careful attention to details and to individual parts of apparatus. By so doing a great improvement in overall frequency response has been effected.

It will be readily understood that a moderate deviation from uniform response, which might be tolerated in individual pieces of apparatus taken separately, would become serious if such apparatus were used as part of a chain, and for this reason a much higher standard is required from individual parts of a chain than is required for the overall performance.

A study of the magnetic and electrical properties of the new series of nickel irons has led to improvement in the design and production of transformers to meet the stringent conditions already mentioned, and it has also made possible the use of much smaller and lighter transformers than hitherto.

By the use of carefully selected iron, built up in thin laminations, it has become possible to produce transformers having a uniform frequency response over quite a wide frequency spectrum, operative on radio frequencies, and it seems probable that this type of transformer may find many useful applications. Distortion arising in iron-core transformers will be largely eliminated as the conditions producing item are becoming understood and avoided.

By the use of new types of valves an economy in valve and battery use has been effected, accompanied by greater range of power output with distortionless working. Improved flexibility of control and switching has been obtained by the use of apparatus mounted on racks, and simple and effective means of mixing programme sources have been produced.

Improved methods of indicating the instantaneous amplitude of the speech currents have made possible the more effective control of the depth of modulation at the transmitters, thus securing a greater average depth of modulation with less blasting, caused by momentarily exceeding the distortionless modulation depth.

Conclusion.

In conclusion, and touching once again on the shortage of broadcasting wavelengths, and the tendency in Europe to employ high-power stations, it is interesting to note that there is a development taking place in the form of the establishment of local receiving stations, the function of which is to pick up the programmes of the high-power stations and re-broadcast them. This is done either on a low-power transmitter working on a common wave, or on a very short wave below 10 m. or the received signals are distributed to the houses in the locality through a system of house-to-house wiring.

Short waves below 10 m. have been found quite useful for local re-broadcasting. The range is small and unlikely to cause interference at a distance, and, subject to the obvious precaution of erecting the aerials on tall buildings clear of obstacles, good results are obtained. In this way first-quality broadcasting can be received in districts not normally served by the high-power stations.

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The service of programme distribution through a house-to-house system is already in use in England and is considerably developed in several Continental countries, in particular in Russia, where for a small monthly subscription one can obtain the use of a good loud speaker of the cone type and two programmes. It has been suggested that it would be cheaper to wire up a whole village and supply each house with a loud-speaker than to supply an equivalent number of receivers. Many of us might prefer not to be tied to the B.B.C. programmes, good as they are, and the fascination of listening to foreign stations is not to be despised. Nevertheless, I believe, if I may venture to prophesy, that we shall ultimately have wireless laid on in our houses, in the same way as the water, the gas, the electric light and the telephone. By then, however, it will no longer be wireless!

I am afraid that in attempting to review so wide a subject as radio communication and practice, I have only been able, as it were, to scratch upon the surface of things. I feel certain that I have omitted to mention important developments in some branch or other and I can only make the confession that specialisation in the many branches of wireless design or exploitation is the order of the day and that it is becoming increasingly difficult to co-ordinate the various branches of investigation and development. Engineers are becoming specialised in the study of transmitting or receiving apparatus, long or short waves, direction finding, valve manufacture, low-frequency apparatus, marine and aircraft apparatus, transmission and propagation phenomena, both with and without wires, even, as I have already mentioned, in the study of frequency allocations and the exploitation of channel in the ether, to say nothing of the erection of buildings, masts, plant and machinery. As a result, the erection of a station of importance is no longer a matter involving the selection for duty of a competent all-round engineer; it often involves the services of specialists in the final tuning-up and adjustment of a modern station.

Surely the lot of a radio engineer is varied, and his study, if he is interested in his profession, all-absorbing.

I should like to express my indebtedness to my colleagues of the Marconi Co., in particular to Messrs. Franklin and Wright, for assistance in collecting data for this address.

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MARCONI SHORT WAVE TRANSMITTER

TYPE S.3

The set described below has been designed to meet the ever growing demand for a medium power general purpose short wave transmitter, which, whilst covering a great range of frequencies, should also embody the requisite apparatus for maintaining constant the radiated frequency to within narrow limits and for securing instantaneous rigidity of the carrier frequency during modulation of the transmitter, without which serious distortion of received speech is commonly experienced.

Other requirements of such a transmitter, all of which have been embodied in the S.3, are : the alternatives of C.W. or I.C.W. telegraphy or telephony, high speed keying and facilities for quickly changing from one radiated frequency to another.

TWO editions of the transmitter have been designed, namely, the S.3A and S.3B, the difference between them consisting only in the range of frequencies covered : that for the former being 18,750-4,000 kcs. (16-75 metres) and for the latter 15,000-3,000 kcs. (20-100 metres).

The aerial power on C.W. telegraphy is nominally 250 watts.

On telephony the nominal carrier aerial power is 135 watts, the degree of modulation being 70 per cent.

For I.C.W. the telephone carrier is modulated 80 per cent., thus giving a nominal aerial power of approximately 180 watts.

Over the greater part of the frequency range the powers are considerably in excess of these figures, and somewhat below it at the highest frequencies.

Before going on to describe particularly the circuits and constituent parts it might be as well first to give a broad outline of these.

The transmitter then, is controlled by a master oscillator, A, Fig. 1, contained in a chamber kept at a fixed temperature to within narrow limits.

The output of this oscillator is amplified by a six stage amplifier B, Fig. 1, in which are embodied an isolating stage and two frequency multiplying stages. All but the last stage of this amplifier employ low filament consumption receiving valves and take their filament and anode supplies from the batteries which provide these supplies for the master oscillator. The anode supply to the last stage is taken from a machine and its filament supply from that used for the power stages.

The output of the master oscillator amplifier controls the first of the two main power stages C, Fig. 1, which, in turn controls the second and final stage D, Fig.1.

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The anode supplies for these last two stages are taken from a common machine, the voltage at the anodes of the first being reduced by a series resistance.

Modulation is effected by the direct current grid method described in the June Number of THE MARCONI REVIEW. In this method modulation is applied to the grids of the final stage, and I.C.W. is obtained by impressing the output from an audio frequency valve oscillator on the grid of the modulating valve. The various components for telephony and I.C.W. are mounted in the Unit E, Fig. 1.

Keying of the transmitter for C.W. and I.C.W. telegraphy is accomplished by a method which provides for speeds up to 150 words per minute with a minimum of apparatus.

The transmitter is designed in such a manner that all adjustments can be made from the front. The time to change from one frequency to another need in no case exceed five minutes.

Having thus briefly outlined the transmitter a more detailed description of the circuits and component parts will now be given.

Master Oscillator.

The Master Oscillator circuits provide for two alternative types of control, namely, by a valve maintained inductance capacity circuit, and by quartz crystal.

The former includes a variable condenser, thus permitting the transmitter to be adjusted to any frequency within its range; whilst the provision of four quartz crystals allows of this type of control on any chosen four spot frequencies.

Changing from the inductance capacity circuit Master Oscillator to any one of the four quartz crystals is effected by a selector switch. This switch can clearly be seen below the vernier control of the variable condenser of the inductance capacity circuit on the front of the Master Oscillator chamber A, Fig. 1.

A calibration chart for the inductance capacity circuit is fixed inside a hinged door in the outer cover of the Master Oscillator compartment. This may be seen in Fig. 3.

Two P.610 valves are provided, both being connected permanently in circuit, except that the positive filament supply of one or the other is broken by a two-way switch external to the Master Oscillator chamber.

This arrangement obviates the necessity of having to open the chamber to replace a faulty valve, an operation which, in addition to interrupting transmission for some minutes, would have the more serious result of cooling the Master Oscillator components, with a consequent considerable drift in frequency which might take some hours to reach stability again.

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As it is, in the event of a valve failure the alternative valve may be switched on and the transmission continued at once without any appreciable change in frequency.

The chamber consists of a brass box lined with heat insulating material and is maintained at an even temperature by heater lamps. These are switched on and off by a relay which has the contacts of a thermostat connected in series with its energising coils.

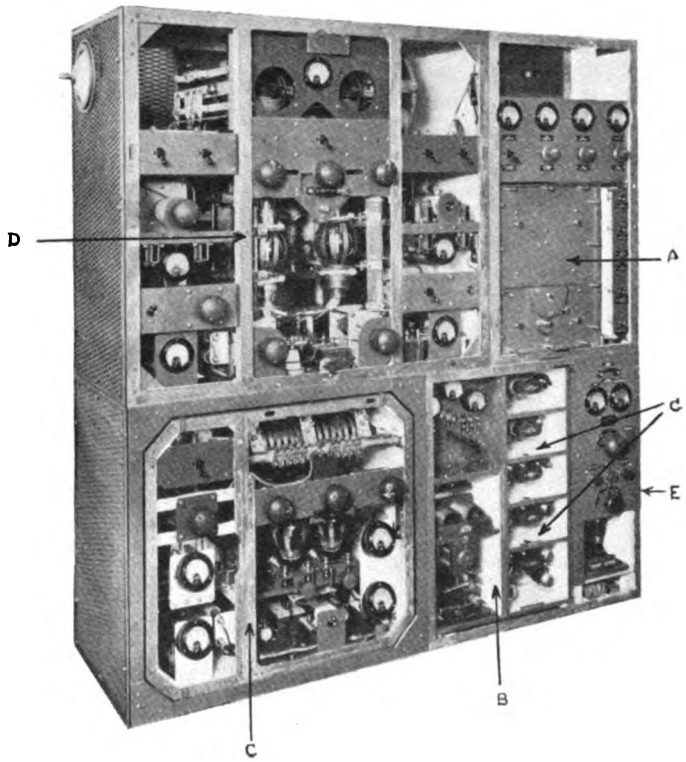

FIG. 1.

In order to cater for very wide variations in room temperature, switches are provided to connect one, two or three heater lamps in circuit. A baffle plate is fitted beside the heater lamps to prevent direct radiation from them striking the Master Oscillator components and thus giving rise to slight rapid changes in frequency each time the thermostat operates.

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A thermometer fixed to the side of the chamber, with its bulb well inside, gives a visual indication to the operator that the temperature control is functioning correctly. The thermometer can be viewed through the window F, Fig. 3, in the outer cover of the Master Oscillator compartment.

The filament and anode supplies for the Master Oscillator valve are provided by batteries. As the battery voltages fall during discharge the filament and anode voltages of the valve can be maintained constant at 5·5 and 220 respectively by means of variable resistances. Suppressed zero instruments, giving good discrimination, enable the operator to maintain the valve voltages to within extremely close limits. The instruments and resistance controls are mounted at a convenient height just above the Master Oscillator chamber.

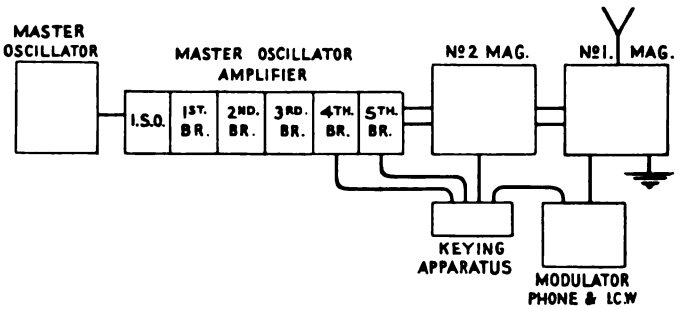

FIG. 2.

As a result of the provisions made for temperature and voltage control and due partly also to the robust and careful design of components, the frequency of the Master Oscillator, whether inductance capacity circuit or Quartz crystal, can be relied upon to remain constant for long periods to within one part in ten thousand after a steady temperature has been reached.

Over short periods of 6 hours or so during which the room temperature and therefore also the temperature gradient through the walls of the Master Oscillator chamber, remain reasonably steady, a constancy of frequency within one part in twenty thousand may be expected. This assumes that the heater lamps have been switched on for at least twenty-four hours to ensure that all the components will have reached a steady temperature. In practice, of course, the heater lamps would never be switched off between transmissions.

Owing to the large range of frequencies covered it is not possible to set the inductance capacity circuit from the calibration chart with a very high degree of discrimination.

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The actual discrimination is as follows :—

Between 4,000 and 7,500 k.cs. average discrimination is 1 in 500.
Between 15,000 and 4,000 k.cs. average discrimination is 1 in 1,000.
Between 18,750 and 15,000 k.cs. average discrimination is 1 in 1,500.

Herein lies the usefulness of the four quartz crystals, for they equip the transmitter with four radiated frequencies which will repeat themselves to within limits which the figures above show to be unapproachable with the inductance capacity circuit.

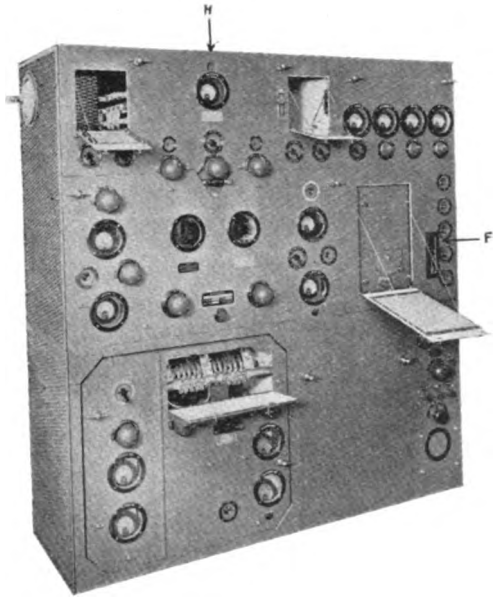

FIG. 3.

If the station equipment includes a precision frequency meter then greater accuracy of setting can of course be obtained, the calibration chart being used as a first guide in that case.

Referring to Fig. 1, it will be observed that the upper part of the front cover of the Master Oscillator chamber is hinged, and thus by removing the seven clamping screws around its edge access is gained to the interior for the insertion of valves, heater lamps or crystals.

All the components are mounted on a micalex base rigidly fixed to the lower part of the front cover, so that in the event of a fault occurring which cannot be localised by inspection through the hinged door the whole of the interior may be withdrawn as a unit for a thorough inspection and test.

Master Oscillator Amplifier and Frequency Multiplier.

This unit B, Fig. 1, comprises six valve stages and an instrument panel, the latter mounting three instruments and a jackfield, whereby provision is made for a visual indication of correct tuning and neutralising adjustment of all six stages.

In Fig. 2 the six stages of the amplifier are indicated as follows :—Isolator, 1st, 2nd, 3rd, 4th and 5th Bridges.

The valve of the Isolator stage is of the four electrode type, S.610, and it is arranged that the grid current of this stage is negligibly small. This ensures that

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anode or grid current variations in later stages, due to keying or modulation, cannot react on the Master Oscillator and cause a variation of frequency.

The valves of the Bridges 1 to 4 are 2-HL.610, 2-HL.610, 2-P.625 and 4-P.625 respectively, and take their filament and anode supplies from the Master Oscillator batteries.

The drain from the L.T. battery is 2 amps. and from the H.T. battery 150 milliamps.

The valves of the 5th Bridge are 2-DET.1 S/W. Their filament supply is taken from that for the power stages, and their anode supply from an independent source of 600 volts 50 watts.

The anode circuits of the Isolator and 1st Bridge are tuned always to the third harmonic of the Master Oscillator frequency in the S.3A, and alternatively to the second or third harmonic in the S.3B. The anode circuits of the 2nd Bridge and of all subsequent stages in the S.3A are tuned to the first, second or third harmonic of the frequency to which the Isolator and 1st Bridge circuits are tuned, and to the first or second harmonic in the S.3B. Thus the final radiated frequency in the S.3A may be the third, sixth or ninth harmonic of the Master Oscillator frequency, whilst in the S.3B it may be the second, third or sixth harmonic.

By this means it has been possible to arrange that the frequency of the Master Oscillator never exceeds 2,500 k.c. This is an important point, for it ensures that a quartz crystal for any radiated frequency shall be robust and reliable.

Mention has been made of the instrument panel for the Master Oscillator and Master Oscillator Amplifier. This can be seen in the top left-hand corner of the Master Oscillator Amplifier Unit B, Fig. 1.

Its object is to provide means of tuning and neutralising all stages of the amplifier with a minimum of instruments. The three instruments, two milliammeters and a galvanometer, are brought out to a three-point plug which may be inserted in any of the six positions of the jackfield.

If, for instance, it is inserted in the position marked 1st Bridge, and the press-button switches up to and including the one above that line of jacks be closed, thus completing the anode supplies up to the 1st Bridge, then one milliammeter reads the feed to the 1st Bridge, the other reads the grid current of the 2nd Bridge, and the galvanometer is included in the grid circuit of the 3rd Bridge, and will show a reading if the 2nd Bridge is unbalanced.

Thus by advancing the three-point plug one position at a time from left to right all stages of the amplifier may be tuned and neutralised.

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This process only needs to be carried out once for neutralising, since the extreme electrical symmetry of the circuits ensures the balance being sensibly independent of change of frequency within the frequency range of the transmitter.

Also, once the tuning condenser settings have been noted down for any particular frequency, the circuits may be reset for that frequency with sufficient accuracy from the calibration chart without resort to the instrument panel.

The tuning condensers are operated by thumb quadrants, the scale readings being observable through small holes G, Fig. 1, in the inter-stage screening partitions.

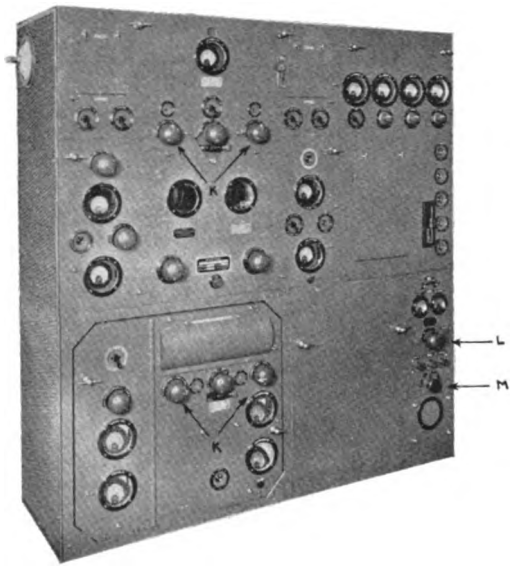

FIG. 4.

For the stages of the Master Oscillator Amplifier more than one value of inductance is required to cover the complete frequency range of the transmitter and plug-in coils are provided for this purpose, the ones not in use being housed in a box which may be seen in Fig. 1 above the Master Oscillator chamber.

Power Amplifiers.

The output of the 5th Bridge of the Master Oscillator Amplifier drives the first of the two Power Amplifiers, C, Fig. 1.

This is denoted as No. 2 magnifier in Fig. 2, and mounts 2-MT.11 S/W valves. Their anodes are fed from the main 2,500-volt supply through a breakdown resistance of 10,000 ohms.

The average feed to the two valves over the frequency range is 100 milliamps, and thus the working anode voltage is 1,500 volts and the average anode input power 150 watts.

The output from the No. 2 Magnifier drives the final Power Amplifier, D, Fig. 1. It employs two MT.12 valves. The full load C.W. anode input is 500 watts at 2,500 volts and the average aerial power on C.W. over the frequency range of the transmitter is 290 watts.

In the two Power Amplifiers plug-in coils are not employed, the necessary variations in inductance for the different sub-divisions of the frequency range being

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accomplished by switches on the inductances themselves. Access to these switches is provided by hinged doors which are shown open in Fig. 3. Calibration charts giving the positions of the switches for each sub-division of the frequency range are fixed to the inside of the doors.

The tuning condensers each comprise a variable condenser having a vernier drive and a semi-variable condenser which may be switched in parallel with the former, one plate at a time. This arrangement results in a very large ratio of maximum to minimum capacity, thus enabling a good average ratio of inductance to capacity to be maintained over the frequency range.

On the handles, K, Fig. 4, for operating the switches of the semi-variable condensers arrows are engraved which point to indicating numbers that register the number of plates in circuit.

Instruments for reading anode feed, grid current and filament voltage of both Power Amplifiers are mounted behind windows, in addition to an H.T. voltmeter and a low reading thermo-ammeter; the last is included in the tuned anode circuit of No. 1 Magnifier and is used for neutralising that stage.

On power the thermo-ammeter is short-circuited and a press-button is provided to remove the short circuit when it is desired to neutralise the No. 1 Magnifier. In order to avoid the instrument being burnt out by inadvertent removal of the short circuit on power a hinged cover plate, H,Fig. 3, is fixed over the press-button and connected by Bowden control to the " Power-Neutralise " switch.

As an indicator for neutralising No. 2 Magnifier the grid current meter of No. 1 Magnifier is used. A press-button underneath the instrument removes a shunt, thus making possible a very critical adjustment of the neutralising condensers.

Aerial.

In the design of the aerial coupling arrangements of this general purpose transmitter attention has been paid to the possibility that in some cases, *e.g.*, when installed in a ship, it may be necessary from practical considerations to use one aerial for the complete frequency range. This implies an harmonic aerial, with resulting great variations in the required electrical constants of the terminating circuit over the frequency range.

For instance, at the lower frequencies, when the length of the aerial is such that a voltage node exists at the aerial terminal, then a parallel circuit of comparatively large values of inductance and capacity is required ; whilst for a current node at the higher frequencies a series circuit of much smaller values of inductance and capacity would be necessary.

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To provide the necessary flexibility three switches are mounted on the front of the transmitter having the following respective functions : to select a larger or smaller variable condenser ; to connect the selected condenser in series or parallel with an inductance ; to select two values of inductance by connecting two coils either in series or parallel.

The inductance coils also provide the coupling between the anode circuit of the No. 1 Magnifier and the aerial.

Even with this degree of flexibility it will sometimes happen that with a particular combination of frequency and aerial length it is impossible to tune exactly the aerial circuit and in order to provide for such cases the coupling coils are designed to make possible a very tight coupling, to ensure always that sufficient energy can be transferred to the aerial fully to load the No. 1 Magnifier.

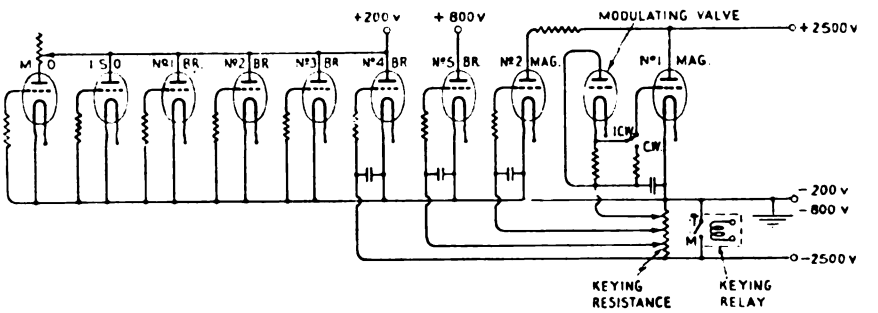

FIG. 5.

A simple harmonic aerial, whilst minimising installation difficulties in certain cases, is not an efficient radiator, and for land stations, once definite working frequencies have been decided upon, a suitable half-wave or multi-half-wave aerial would be used for each frequency.

Telephony and I.C.W.

The type of modulation employed is that known as the Direct Current Grid method, in which the No. 1 Magnifier grid bias resistance used for C.W. telegraphy is replaced, for telephony and I.C.W., by the filament anode resistance of a small triode.

On the grid of this triode is impressed the speech frequency voltage in the case of telephony or the output from an audio frequency valve oscillator for I.C.W.

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A dry cell battery of about 80 volts provides the grid bias for adjusting the filament anode resistance of the modulator valve to the value required to set the No. 1 Magnifier to the carrier anode input.

The modulator valve is an L.S.5 and its filament is heated by A.C. from a small combined motor alternator and D.C. generator. A.C. is used for this purpose because, with this method of modulation, the anode of the modulator valve is at earth potential and A.C. heating avoids the inconvenience of an insulated battery. A complete balance for hum is obtained by means of a potentiometer connected across the valve filament.

The D.C. generator provides the anode supply for the L.S.5 valve of the audio frequency oscillator whose output is impressed on the grid of the modulator valve for I.C.W. telegraphy. A choice of three notes (600, 900 or 1,200 p.p.s) is available, the selection being made by a three-position switch, M, Fig. 4, on the front of the Modulator panel.

Selection of the type of transmission, whether C.W. telegraphy, I.C.W. telegraphy, or telephony, is effected by means of a seven-pole three position switch, L, Fig. 4, which performs the following operations: on I.C.W. and telephony it disconnects the No. 1 Magnifier grid circuit from the C.W. grid bias resistance and connects it to the filament of the Modulator valve and starts up the combined motor-alternator and generator; it connects the primary winding of the line-to-grid transformer to the speech input for telephony and to the audio frequency oscillator for I.C.W., completing the filament circuit of the oscillator valve in the latter case; on telephony it short circuits the keying resistance, thus putting the transmitter permanently on "mark."

A galvanometer in the grid circuit of the modulator valve serves as an indicator of over modulation.

In the I.C.W. position of the transmitter selector switch this galvanometer is short circuited to avoid damage from the grid current which is permitted on I.C.W. for the sake of deep modulation, but which of course is inadmissible on telephony.

Provision is made for local microphone or line input by a two-way switch. The unequal impedances of the line and local microphone are allowed for by connecting the latter to a suitable tapping point on the line-to-grid transformer. Sockets are provided on the front of the panel for the local microphone.

All the components for obtaining telephony and I.C.W. modulation, with the exception of the motor alternator and the grid bias battery, are contained in the one unit, E, Fig. 1. Connections for the supplies are by flexible leads, thus allowing the unit to be withdrawn from the main framework for inspection and the location of faults.

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The average value of the telephone carrier aerial power over the frequency range of the transmitter is 150 watts, and the degree of modulation obtainable without running into grid current in the modulating valve is 70 per cent.

As has previously been stated, grid current is permitted on I.C.W. telegraphy and the degree of modulation consequently is about 80 per cent. The average aerial power on I.C.W. telegraphy is therefore approximately 200 watts.

Keying.

The outstanding advantages of the well-known method of absorber keying are : (1) stabilisation of anode supply voltage by providing a spacing load equal to the marking load, (2) elimination of effects due to the transit time of the keying relay, and (3) making the keying of a transmitter a voltage operation and therefore sparkless.

Unfortunately, for a medium power transmitter such as the S.3, the additional apparatus and filament power required for absorber keying can hardly be justified for reasons of both cost and space.

However, the method of keying employed in the S.3 provides completely for (2) above, and to a very considerable extent for (1) and (3), whilst the additional apparatus required consists only of a tapped non-inductive resistance of about 1,000 ohms and, of course, a high-speed keying relay. The actual resistance used is two woven mat resistances, each six inches square.

Briefly, the method consists in allowing the power magnifier valves to take a dead loss feed on " space," thus working them as absorbers, and to use the voltage arising from this feed flowing through the keying resistance both completely to " block " an early stage, so that the driving voltage is removed from all subsequent stages and to set the latter at that point on their characteristics where they will be dissipating the maximum permissible anode loss.

A simplified diagram illustrating the arrangement is shown in Fig. 5.

It will be observed that the low potential end of the grid bias resistance of the stage to be " blocked " is connected to the negative end of the keying resistance, which is connected between the negative side of the main H.T. supply and " earth." The grid bias resistances of the subsequent stages are connected to tapping points on the keying resistance such that the voltage between each tapping point and " earth " is the value required to set each stage as described above.

The contacts of the keying relay are connected across the keying resistance, so that on " mark " the resistance is short-circuited and the grid bias resistances are then connected to earth in the usual manner. The small value of resistance between

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the tapping point and " earth " on " mark " is negligible compared with the value of the grid bias resistances.

In the S.3 it is the 4th Bridge of the Master Oscillator Amplifier which is " blocked " on " space." The Master Oscillator and the Islator and 1st, 2nd and 3rd Bridges of the Master Oscillator Amplifier continue to function as on " mark," which fact makes for complete stability of frequency during keying.

The load on the main H.T. machine on " space " is about 45 per cent. of the load on " mark, " and with average machines a voltage regulation of about 6 per cent. may be expected between " mark " and " space."

The transmitter will key satisfactorily up to 150 words per minute.

Keying for I.C.W. telegraphy is accomplished in the same manner, the anode of the modulator valve being connected to the keying resistance.

In order to allow the negative voltage from the keying resistance to arrive at the No. 1 Magnifier grids on " space " a high resistance leak is connected from anode to filament of the modulator valve.

Time Required for Changing Frequency.

The time required to change from one frequency to another depends upon whether a complete calibration of all adjustments has been made for the new frequency and also whether or not the two frequencies lie in the same sub-division of the frequency band.

If a calibration exists, then, in the worst case, that is, one in which the greatest number of coil changes and so on have to be made, five minutes is sufficient ; on the average four minutes is enough and three minutes in the most favourable case.

F. C. Lunnon.

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THE UNEQUAL FADING OF CARRIER AND SIDE BANDS

The Technical Editor of THE MARCONI REVIEW *has much pleasure in publishing the following correspondence which he has received on the above subject which was discussed in Mr. A. W. Ladner's article entitled "The Phase of Carrier to Side Bands and its relation to a Synchronous Fading Phenomenon," which appeared in* THE MARCONI REVIEW *for August*, 1930.

" Sir,—I was very interested in your August number of THE MARCONI REVIEW with particular reference to the article which begins on page 25 and shows the oscillograph results of artificially shifting the phase of side bands with respect to carrier.

2. The phenomenon of unequal fading of the carrier and the modulated components has been noticed by me on many occasions, particularly on the long distance reception. It has been observed on signals from 5SW towards the arrival of daylight at this end, when signals are beginning to fade out completely, and on the approach of darkness at the transmitter when signals are just beginning to be audible here. I have also noticed it on American signals under somewhat similar conditions.

3. It would be interesting to know whether any such effect is heard on a system which uses a single side band with suppressed carrier, where the carrier is reintroduced in the demodulator. If Mr. Ladner's explanation is the correct one, there should be no trace of such effect on for example the London-American telephone circuit via Rugby and a transmission on this system should be subject to uniform fading only, a much easier condition to compensate. I look forward with interest to further articles on the subject, and should be very glad to know the answer to my query, if Mr. Ladner could find time to answer it. I am particularly interested in the single side band system as I have carrier current telephone channels in use here which work in this manner. Incidentally it is found that a considerable shift of the carrier when reintroduced at the demodulator can be tolerated on speech before serious distortion is noticed."

Posts and Telegraphs,
Ipoh, Federated Malay States. G. WILDE.
27th October, 1930."

" Sir,—With reference to Mr. G. Wilde's letter of the 27th October, 1930, I do not think there is very much I can add to what has previously been written, except that, as Mr. Wilde surmises, recent experiments on single side band work on very short waves do indicate that such a system is more immune from the type of fading described. It is not observable on the long wave Rugby-America service because this type of fading is not in evidence anyway on these long wavelengths, and on the very short wavelengths there is no regular single side band service working because of the difficulty of getting a sufficiently constant frequency ; but experiments that Messrs. Langridge and Wilson carried out at Terling where they attempted to work single side band did indicate that receptions were much better from the fading point of view.

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It is interesting too—that Mr. Wilde has observed the same type of fading. It might be of interest to note that with ordinary speech considerable shift of carrier can be tolerated and considerable change of frequency also when the modulation is ordinary speech, but no such changes can be tolerated if music is transmitted as the combination tones are changed as well as the main tones.

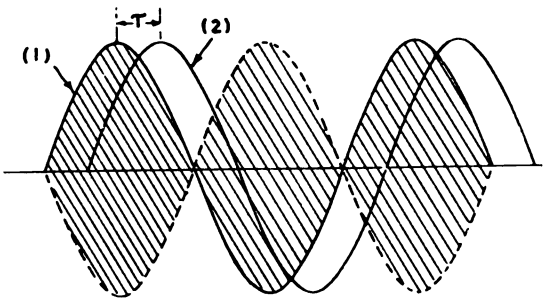
Marconi College, Chelmsford. A. W. LADNER.
December 31st, 1930."

" Sir,—On analysis I find Mr. Wilde's letter a little difficult to understand.

The difficulty turns on the interpretation of the phrase in the first sentence (2) i.e. ' Modulated Components.'

If this refers to the side wave alone as it seems to—paragraph (3) is unintelligible for in a suppressed carrier system it is meaningless to talk of unequal fading of carrier and side bands if the carrier is absent.

I therefore imagine what he calls the ' Modulated Component ' is the rectified beat tone between the side waves and the carrier.



If this is the case the ' Modulated Component ' which depends on the product of the intensities of the side bands and the carriers—as well as their relative phases certainly fades in a different manner from the carrier alone. But this relative fading is not only caused by a change of phase of the side bands relative to carrier but also on the relative change of intensity of the side band.

Suppressed carrier will cure the first form of fading but not the second.

With regard to the question in paragraph (3). Suppressed carrier transmission is used at Rugby on long waves (5000M) where effects of fading are much less marked than on short waves, and I personally have not observed the transmission sufficiently to judge if the above effect exists.

On short waves where the effect of unequal fading of modulated components and carrier is well known, suppressed carrier transmission has not been successful and, as far as I am aware, attempts that have been made have failed on account of insufficient frequency stability. Whether the main cause of the unequal fading of ' Modulated Component ' is different amplitude fading of the side waves relative to the carrier or is due to a relative phase shift I am not prepared to say, but there is an effect akin to the one discussed which I am convinced is due to relative phase shift of the side bands. It shows itself as an apparently more or less permanently

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reduced ' Modulated Component ' as compared with the carrier, and is especially liable to occur within the skip distance.

The explanation of this effect is based on the relative phase shift of side bands and carrier. In a scattering field the resultant is the sum of a number of contributions which travel by various devious paths.

If curve (1) represents the received modulated signal by one path and curve (2) that by another path, where T is the delay time, then on the face of it, it is quite obvious that the modulation on the two signals together is reduced by the filling up of the second signal. To interpret this as an effect of the relative phase shift of the side waves it is sufficient to note that a phase shift of the side waves produce a corresponding phase shift of the modulated envelope. Curve (2) therefore represents the effect of a phase shift in the side bands.

We have therefore to expect that in a scattered field the phase of the side bands is changed by a random amount.

Since there is a decrease in ' Modulated Component ' for all changes in phase from the normal arrangement the resultant ' Modulation Component ' must always be decreased in comparison with the carrier. This effect is very marked at times in the skip distance.

It is to be remarked that a frequency modulation may produce an audio note in a receiver which will fade differently from the carrier.

Research Department,
Marconi's Wireless Telegraph Company, T. L. ECKERSLEY.
Chelmsford.
January 17th, 1931."

(Note by Technical Editor.—An article on this subject by Mr. T. L. Eckersley will appear in the next issue of THE MARCONI REVIEW, *in which he amplifies the views stated above.)*

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MARCONI NEWS AND NOTES

THE VATICAN WIRELESS STATION

Marchese Marconi (extreme left) with Father Gianfranceschi, Director of the station (third from left), and officials in the transmitter building at the Vatican wireless station.

THE short wave broadcasting and wireless telephone and telegraph duplex station which has been supplied by Marconi's Wireless Telegraph Company to the Vatican City and which was formally inaugurated by His Holiness the Pope on February 12th, has a world-wide range.

The new transmitter, which in its main features follows the design of the famous Marconi short wave high-speed Beam transmitters which are used in the British Imperial Beam stations, was manufactured at the Marconi Works at Chelmsford.

The complete installation consists of four main panels, and is designed for telephony and high-speed telegraphy on either 19·84 or 50·26 metres. The first of the four panels is the main magnifier unit for both waves. The second panel contains the intermediate magnifiers and the new Marconi-Franklin valve master-

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drive unit for the shorter wavelength. The third panel comprises the intermediate magnifier units and master-drive unit for the longer wavelength, while the fourth panel is a combined modulator for telephony and absorber keying unit for high-speed telegraphy.

Masts and aerials of the Vatican wireless station.

Rating on Telegraphy and Telephony.

On telephony the transmitter is rated to deliver from 8 to 10 kw. of unmodulated carrier wave energy to the aerial feeder system, the output depending slightly on the wavelength used. The normal degree of modulation is 80 per cent.

The rating on continuous wave telegraphy is 13-15 kw. to the aerial feeder.

Two transmitting aerials of the Marconi "Uniform" type are provided, one aerial for each wavelength. This type of aerial has been developed recently by the Marconi Company and is an improved type of vertical short wave aerial.

Both aerials are suspended and insulated from a triatic slung between two self-supporting lattice steel towers 61 metres in height and 90 metres apart.

The energy from the transmitter building is conveyed to the two aerials by two separate concentric copper tube feeders similar to those used in the British Imperial Beam stations. The transmitter building itself is situated near the railway terminus in a part of the grounds in the Vatican which is surrounded by a Roman wall 45 feet high, whilst the masts are placed outside this wall. In order not to destroy the amenities of the Vatican gardens a tunnel 43 metres long passing under the Roman wall has been constructed to accommodate the aerial feeders.

Every effort has been made to harmonise, as far as possible, the transmitter building and aerial towers with the graceful surroundings of the Vatican City. The transmitter building is of sober but pleasing architectural design; and the tops of the masts are finished off to give a Bishop's mitre effect which greatly enhances their appearance in silhouette.

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The transmitter building contains a spacious transmitter room with land-line control tables, an amplifier control room, receiver room, accumulator room, machine room, valve and general stores and general office.

Reception.

A special receiver, partly made of standard parts of the normal telephone and high-speed Marconi receiver and telephone terminal four-wire two-wire equipment, will secure good telephone and telegraph duplex communication between the Vatican City and any part of the world. This receiver is situated in one of the rooms of the transmitting station and utilises a vertical aerial placed at a distance of only a few yards from the sending aerial. This receiving aerial is suspended from the same triatic which carries the sending aerial and its length is adjustable from the receiving room.

The new wireless station which may be considered to represent the latest word in short wave technique, to which such far-reaching contributions have been made by Marchese Marconi and his able assistants, has been erected by Italian engineers under the personal supervision of Marchese Marconi. It will not only provide the Vatican City with a radio telegraph and telephone link with distant parts of the earth, but when required will also enable the voice of His Holiness the Pope to be broadcast throughout the world.

During tests which took place during the week preceding the opening, the Vatican station carried out good clear telephone communication with Australia, India, South Africa, Argentina, Canada and the United States, and with London, Paris, Berlin, Madrid and other European capitals.

Wireless Beacon Stations.

THE extension of facilities for navigation by wireless through the installation of automatic wireless beacon stations has become an accepted practice in the leading maritime countries. Experience in operation has shown that this type of wireless beacon provides the most suitable and economical form of assistance for the many ships now fitted with wireless direction finders—an instrument which in accordance with the Safety of Life at Sea Convention signed by 18 nations, will in July this year become compulsory equipment on passenger vessels of more than 5,000 tons.

Marconi automatic wireless beacons can be installed in lightships and light-houses or in other positions already familiar to navigators, from which they broadcast in all directions a distinctive signal at stated periods so that direct bearings can be taken. The transmitters are automatically controlled and require no skilled personnel for their operation.

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The Marconi automatic wireless Beacon at North Saddle Island, China.

They have been adopted for use by the British coastal authorities and are becoming increasingly used abroad, a station of this type having been recently completed at North Saddle Island, near Hongkong, China. Further Marconi beacons are now to be installed at the Roumanian Port of Constanta on the Black Sea coast, and on Kennery Island at the mouth of the harbour at Bombay, India.

The beacon station at Constanta will be the second erected to the order of the Roumanian authorities, one being already in operation at Cap Caliacra, approximately 55 miles to the south. The distinctive signal for the Constanta beacon will consist of the Morse call " — · — · ", repeated five times during a period of twenty seconds, and then a pause of ten seconds. This signal will be repeated nine times in 4½ minutes, followed by a silent period of 15½ minutes, except in bad weather when it will be transmitted continuously.

The Kennery Island beacon is the first to be installed in Indian waters.

Both the new beacon stations are to be of the standard Marconi W.B.2 Type, operating on a power up to 1 kilowatt, that for Kennery Island being specially arranged for tropical service.

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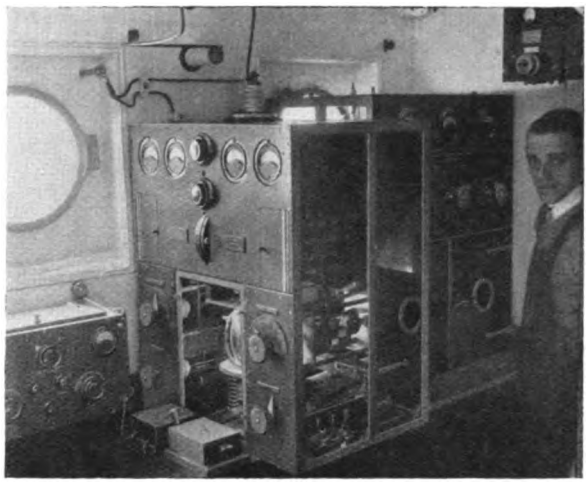

Marconi short wave transmitter installed on the s.s. " Oropesa *" for the use of the Prince of Wales.*

Keeping the Prince of Wales in Touch.

A MARCONI short wave wireless transmitter and receiver which has been specially installed for the use of the Prince of Wales on the Pacific Steam Navigation Company's liner *Oropesa*, on which he is travelling to South America, will enable him to maintain throughout the voyage constant and direct communication with this country through the short wave wireless coast station at Portishead near Bristol.

Although an increasing number of ships now carry short wave equipment for direct communication over long distances, no ship fitted with short wave wireless apparatus for communication with England has yet made the voyage along the Pacific coast of South America. Recent experience in short wave wireless communication at sea indicates, however, that at no time during the voyage should the Prince of Wales find any difficulty in maintaining direct communication with England.

With such apparatus, for example, the Australian liner *Jervis Bay*, when docked in London has communicated direct with Sydney, and the Royal Mail liner *Asturias* regularly exchanges messages with the Portishead station when off Buenos Aires.

While the short wave wireless set on the *Oropesa* is carrying out communication with Great Britain the normal wireless equipment will be used for navigation and the exchange of messages with local ship and shore wireless stations on the run through the Caribbean Sea, the Panama Canal, and down the South American coast.

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THE MARCONI REVIEW

No. 29. *March-April, 1931.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

WIRELESS DIRECTION FINDING SYSTEMS FOR MARINE NAVIGATION

The importance of direction finders in marine navigation has long been recognised by companies exploiting marine wireless gear, who have developed their marine direction finders in the past few years to a very high degree of efficiency.

The general schemes of direction finding at present used in marine practice fall into two distinct groups :—

(1) *The Marconi-Bellini-Tosi system exploited by the Marconi organisation, who are the holders of the Bellini-Tosi patents.*

(2) *The rotating frame method exploited by S.F.R. in France, Telefunken in Germany, and R.C.A. in America.*

The above classification does not include the Robinson Rotating Frame System, which was originally designed for aircraft working, and which has been used at sea for some years.

The object of the following article is to give some idea of the relative merits of the two systems as regards marine practice.

THE past few years have conclusively proved what an extremely valuable navigational aid a marine direction finding receiver can be. There are numerous examples of wireless direction finders having been the means of saving life at sea, a fact which has been so far recognised that the Safety of Life at Sea Convention has demanded all passenger ships of 5,000 tons and above to be fitted with direction finders.

Although the importance of direction finders as an aid to navigation is now appreciated to the full, it is a regrettable fact that there is widespread ignorance of the fundamental principles and hence of the comparative merits of their various applications; it is the purpose of this article briefly to explain and compare the two systems in general use, namely the Marconi-Bellini-Tosi system and the rotating frame aerial system marketed by various other companies interested in marine communication.

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None of the many possible variations of these systems has been adopted to a sufficiently large extent to merit consideration ; nor need we confuse the subject by discussing the different systems of directional transmission. In passing, however it is perhaps worthy of mention that the purpose of the ever-growing number of wireless beacons is merely to ensure the provision of wireless signals from known points of reference, that is to say, they are not themselves directional transmitters, they emit no beam and they exist solely for the benefit of ships upon which direction finding receivers are installed.

Appreciating the potential importance of direction finding in marine navigation, and having in mind the fact that the highest possible degree of accuracy was essential if the system were to become that indispensable safeguard it has, the Marconi Company were very early occupied in designing apparatus suitable for marine use. Holders of the Bellini-Tosi patents, the Company had already demonstrated in other fields the unquestionable superiority of the Marconi-Bellini-Tosi system, and it was obvious that there could be no decision but to incorporate Bellini-Tosi principles in the design of their marine apparatus. The pre-eminence of this system has been continuously maintained, throughout the rapid developments of recent years.

Basic Principles.

The basic principle upon which all systems of directional reception depend is that an aerial consisting of a simple loop of wire has receptive properties at a maximum in the plane containing the loop and at a minimum, or in the ideal case, zero, at right angles to this plane. Little consideration is necessary to realise that by connecting a suitable wireless receiver to such a loop, the latter being rotatable and fitted with compass scale and pointer, a very simple form of direction finder is obtained. Rotation of the loop through one complete revolution will produce two positions of maximum and two of minimum strength of signals from any continuously transmitting station to which the receiver is tuned. It will be found that, unlike the maxima, the minima are extremely sharply defined ; for this reason, observation of minima is the generally accepted method of reading wireless bearings.

A simple direction finder of the type described has the failing of 180° ambiguity ; that is to say, during one revolution of the loop two positions of minimum strength will be observed on any one transmitting station. These two positions should obviously be 180° apart and of course, only one indicates the correct bearing of the transmitting station.

Obviously such ambiguity could have very serious consequences in certain circumstances, but fortunately it is possible to embody a device for the purpose of indicating or "sensing" the correct bearing of the two observed.

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To fulfil condition (1) the usual site chosen is the bridge. This may not be convenient on ships carrying only one operator where the fitting must be such that operation can be performed from the wireless cabin. Fitting near the wireless telegraphy cabin may be impossible owing to ship's structures. In the Marconi-Bellini-Tosi system the frames may be placed at any distance up to 100 feet from the receiver, which fact permits a wide choice of frame site.

The rotating frame system has very limited flexibility in this respect. Driving the frame at a distance of 100 feet would generally be impossible and even if possible, the elaborate mechanism necessary would be very costly, as also would be the screening of the cables between frame and receiver. Again, it is doubtful if any mechanism would be sufficiently accurate over distances greater than 20 feet.

On some ships it is quite impossible to instal rotating frame apparatus satisfactorily.

Calibration.

In every case it is essential, after installation of a direction finder on a ship, to calibrate the deviation of incoming waves due to the ship's structure. Provided the apparatus has been correctly installed, the calibration usually consists of taking a number of wireless bearings and checking them against corresponding visual observations. The necessary corrections for different observed bearings may then be recorded for future use. The corrector may take the form of a table or curve of corresponding observed and true bearings to which reference may be made, or a distorted scale or other device for direct reading of the corrected observation.

In the Marconi-Bellini-Tosi, a simple adjustment is made within the instrument and no corrections are necessary thenceforward, the readings observed being " true." Some rotating frame systems incorporate a mechanical corrector on the hand-wheel.

Owing to the fact that the Marconi-Bellini-Tosi frames maintain a constant relationship to the ship's structures, the system has enormous advantages over the rotating frame system, which varies its relationship for each direction of incoming signal. It is this constant relationship which permits the use of the simple correcting adjustment referred to ; for instance, the greater receptive properties of the system in the fore and aft line of the vessel would lead to a cramping of bearings towards that line but for the fact that the fore and aft frame aerial is proportionately smaller than its partner. This course is obviously impossible with the single rotating frame.

Comparatively few observations are necessary to calibrate the fixed frame system in the general case, the work occupying about five minutes. The usual practice when calibrating the rotating frame system is to swing the ship through 360° and to observe some 30 or 40 bearings before constructing a curve. This procedure in all cases occupies at least 45 to 60 minutes and entails considerable expense to the shipowners.

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Operation.

There are two methods of taking D.F. bearings, namely "Swing" and "Point" methods. The Swing method consists of matching readings of equal strength on either side of the minimum and taking the mean reading. The arc of swing with the Marconi-Bellini-Tosi system is only about 5° on a normal shore station at 80 miles distance. Improvements in receiver design have made this possible; a few years ago a swing of 20° to 40° was more usual.

Point bearings, which are a feature of a number of rotating frame systems, are obtained by means of a special exterior vertical aerial and an additional manipulating knob enables the operator to reduce the "arc of swing." Under ideal working conditions the arc would be approximately 3° at the same distance from the shore station.

In actual practice, however, owing to interference, conditions are rarely ideal, and it is seldom that shore stations send for long enough to permit manipulation of the compensating knob. Consequently, under normal marine conditions, the refinement of point bearings is not so valuable as would at first sight appear; in fact, although it is used when taking observations on continuous wave signals, it is rarely used on Spark or I.C.W. transmissions.

Experienced operators have strongly condemned the point bearing feature as unsound, taking this standpoint from the following considerations:—

(1) Swing bearings may be taken much more rapidly.
(2) Less adjustment and manipulation necessary for swing bearings.
(3) The swing bearing method permits direct reading of the bearing in the Marconi-Bellini-Tosi system without the necessity of making quadrantal error corrections. (This applies equally to the rotating frame systems if a mechanical correcting attachment is provided).
(4) The point bearing of say 3° arc is of little more value than the swing bearing of say 5° arc obtained under similar conditions.

The "Sense" Device.

It is neither necessary nor desirable to dwell upon the theoretical principles of the device previously referred to herein for the purpose of surmounting the difficulty of 180° ambiguity. Suffice it to say that by arranging for signals to be received at one and the same time from both the frame system and a non-directional aerial, provided that certain precautions are observed, an indication as to which of the two minima is correct may be obtained.

It will occur to the reader that the constant use of this device would permit correct readings in the first instance in a single operation. Unfortunately, however, appreciable errors are liable to be experienced if that course were adopted and steps are necessary to discourage any attempt to read "sensed" bearings directly.

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The " sensing " operation proves to be seldom necessary in practice, owing to the fact that the direction of a transmitting station, unless on another vessel, is generally known to within limits. Obviously, resort need only be had to the " sense " device, when doubt exists as to which bearing of two, 180° apart, is correct.

Only the following two operations are necessary to " sense " a bearing in the Marconi-Bellini-Tosi system :—

(1) Move a small Key Switch from " Bearing " to " Sense " position.

(2) Rotate the search coil, with which a minimum has already been found and to observe whether this minimum exists in relation to the " sense " pointer ; if not, it will be found that the opposite minimum does, but that may be assumed if desired without examination.

The total operation is extremely simple and occupies but a few seconds.

A very complex procedure is necessary to " sense " rotating frame bearings in the systems developed for Mercantile Marine use. Having taken a bearing by rotating the frame, in the normal manner, the following operations are required :—

(1) Put coupling pointer off zero position.
(2) Switch tuning switch to the appropriate waverange.
(3) Tune the vertical aerial to the incoming wavelength.
(4) Move coupling pointer to zero and further adjust the point.
(5) Rotate the frame through 90°.
(6) Move coupling pointer to find the minimum position and observe the reading on the coloured pointer on the handwheel coinciding with colour on the coupling pointer.

It will be agreed that there is no comparison between the two systems in the matter of simplicity of operation of the " sense " device. In fact, this is conceded to the extent that certain rotating frame systems developed for other than Mercantile Marine use, are being simplified, the modification following the Marconi-Bellini-Tosi lines.

Vertical Aerials.

That a " vertical " aerial, for non-directional reception, is an essential addition to a marine direction finding installation, will now be apparent. An exception would imply omission of the " sense " feature.

Modern Marconi-Bellini-Tosi installations do not require a separate aerial, the metal screening of the frame acting in its stead.

The saving in expense, the avoidance of unnecessary deck cutting and the elimination of unsightly additions to the aerial array are a few of the advantages claimed for this innovation.

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Electrical Induction.

Successful operation of directional receiving apparatus on shipboard depends to a very great extent upon the amount of interference experienced from the ships' electrical machinery. Sparking of commutators of running machinery, the operation of switches, varying contacts in apparatus of all descriptions, all add their quota to the background of noise above which the operator must hear his signals. With any direction finder the operation requires the location of a reading of little or no signal strength but in searching for this reading the operator has to face a constant noise level.

The problem yearly becomes more formidable, owing to the increasing use of electrical machinery in marine practice.

Actual experience shows in this respect also the undoubted superiority of the Marconi-Bellini-Tosi system and in fact, cases have occurred in which the rotating loop system has been an impossible proposition, its rejection in favour of the Marconi-Bellini-Tosi system having resulted in thorough satisfaction.

The latter system owes its superiority to the following :—

(1) Cheap, simple, yet efficient screening. (The relative difficulties in screening adequately the leads from frame to receiver have been discussed earlier in this article).

(2) Flexibility of frame site, which permits the installation of the frame at the most induction-free position within 100 feet of the receiver, provided of course that due regard is paid to the two requirements previously mentioned.

Receiving Apparatus.

Although the necessary amplifying, tuning and detecting apparatus is not strictly concerned with the function of direction finding and, within limits, any suitable receiver could be used with either aerial system, it is extremely important that any amplifier designed to work in conjunction with a direction finding system should not affect in any way, the operation of the aerial system. It is the policy therefore, of the better-known wireless companies to design the associated receiving apparatus according to their own discretion and to satisfy a standard of selectivity and amplification which should meet most requirements. Unquestionably they should continue to market complete installations rather than to leave the onus of choice with the user. Not the least important advantage of this policy is standardisation and consequent economy.

In these circumstances, a brief comparison of receiving apparatus would appear to be justified. Receiving apparatus included in the majority of marine direction finding equipments falls generally within one of three classes, under the following headings :—

(1) "Screened Grid" Receivers.

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(2) " Straight " Receivers.
(3) Superheterodyne Receivers.

The first class represents the very latest development in modern valve design. Valves of the screened grid type, when used in properly designed receivers, are so far superior to valves of the conventional type that the comparative merits of receivers can no longer be judged by the number of valves used.

For various reasons, an appreciable amount of high frequency amplification is necessary in a marine direction finder and the first mentioned class of receiver, as standardised with the modern Marconi-Bellini-Tosi system, comprises two screened grid stages, amply meeting requirements of amplification and selectivity. A detector and a low frequency amplifying stage follow.

Rotating frame systems generally employ receivers of the second or third classes. Dealing with the second class, *i.e.*, the " straight " receivers, these frequently comprise as many as four high frequency stages and three low frequency stages, in addition to the usual detector. The high frequency stages, however, do not employ screened grid valves, the circuits are complex, manipulation difficult and faults are by no means easy to locate.

Superheterodyne receivers while possessing the advantage of simple manipulation —simpler even than those of the screened grid class—have the following serious drawbacks :—

(A) They are extremely sensitive to interference from the ship's electrical machinery. (In some cases their rejection on this score has been essential. On a certain ship, for instance, in order to get results it was necessary to replace the rotating loop-superheterodyne combination with Marconi-Bellini-Tosi fixed frames and special receivers).

(B) They are peculiarly susceptible to interference from unwanted stations, even though the receiver may be tuned to a wavelength remote from that of the interfering stations. (Tests made over one year by one shipping company resulted in superheterodyne and rotating frame equipment being replaced by Marconi-Bellini-Tosi frames with special apparatus).

Waverange.

The waverange over which a direction finder is capable of working does not depend upon the type of frame system employed, but, as in the case of receivers various manufacturers have standardised their instruments in this respect and the subject is therefore entitled to mention.

In the latest Marconi-Bellini-Tosi marine system the very wide range of 180 to 1,600 metres is covered. This feature renders the apparatus equally valuable for use on trawlers where the 220 metres wavelength is used. Further advantages

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are that the direction finder can be utilised for the reception of gale warnings, weather reports and other matter transmitted on various wavelengths by broadcast stations, and for the purpose of taking bearings on these stations. Transmitting as they do throughout many hours of the day and night they may well be regarded as additional wireless beacons.

Whilst emphasizing the fact that there is no fundamental reason why other systems should not offer equal facilities, it is believed that as regards the Mercantile Marine the Marconi-Bellini-Tosi system alone covers a wider range than 450 to 1,200 metres.

Summary.

Heading.	Marconi-Bellini-Tosi System.	Rotating Loop Systems.
Frame Design	Two fixed metal shrouded loops approximately 2 ft. 6 in. diameter at right angles to one another (a smaller unit is available where space is confined).	One metal shrouded loop about 2 ft. 6 in. diameter capable of rotation on ball bearings.
Mechanics...	Rotation of small goniometer search coil by finger and thumb. No wind pressure to contend with. Ideal for Marine work. No brush gear troubles. No contact troubles, eliminating all electrical noise due to varying contacts.	Rotation of whole frame irrespective of wind pressure. Brush gear trouble and maintenance if frame is continuously rotatable. Mechanics much more complex.
Screening	Complete, efficient and inexpensive.	Screened cables cannot be used and effective screening is not only difficult but expensive and becomes more so as distance between frame and receiver increase.
Site of Frame	Clear field required. Centre line of ship required if possible.	Clear field required. Centre line of ship required if possible.
Flexibility	Frame can be fixed at any distance up to 100 ft. from receiver without any complex mechanism or costly screening of leads between transmitter and receiver.	Frame must be driven, and if far from receiver this means a costly fitting of frame drive mechanism and elaborate and expensive screening of leads from frame to receiver.
Receivers	4-valve, including S.G. H.F. stages, offering maximum selectivity, amplification and manipulative ease with minimum of trouble, maintenance cost and interference from local electrical disturbances.	(A) Straight circuits have eight valves which increase maintenance costs, render manipulation difficult, and necessitate a large number of controls. (B) Super heterodyne receivers possess very simple controls but suffer from drawbacks of interference and ships' noises, also harmonics from outside stations.

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Heading.	Marconi-Bellini-Tosi System.	Rotating Loop Systems.
Wave Range	Wave range on marine design 180—1,600 m. This allows D.F. to be used on trawlers working on 220 m. and on broadcast stations for weather reports and as beacons.	Both (A) and (B) above 450—1,200 m.
Calibration	In the general case visual and D.F. checks on 45° points very quickly and cheaply carried out. Five minutes usually sufficient time required. Calibration choke set and bearings read quickly. Re-calibration can be done easily and quickly. The Marconi-Bellini-Tosi system once installed remains a constant relative to ship structures irrespective of direction of incoming signal.	In all cases a complete Q.E. curve must be taken and this takes at least 45—60 minutes. All bearings must be corrected by Q.E. curve and a mechanical corrector must be fitted and adjusted. Re-calibration means a repetition of the above process and is laborious. The rotating frame system varies its coupling relative to ships' structures for each direction of incoming signal.
Taking of Bearings ...	Swing bearings over narrow arcs (0°—10°). This is found quickest under Marine conditions. On spark and I.C.W. swing bearings almost as good as point bearings on rotating frame system.	Point bearings (0°—2°) on C.W. These involve (A) additional adjustment; (B) more time to take bearing. On spark and I.C.W. the additional adjustment for point bearings does not greatly reduce arc of swing against that on Marconi-Bellini-Tosi system.
"Sense" or True Bearing	Extremely simple and no possibility of making error.	Extremely complex and slow in the Mercantile Marine design and quite a good chance of making errors unless well versed in manipulation of set.
Vertical Aerials	(1) Not necessary for taking bearings. (2) Necessary for "sense" bearings. Incorporated in frame design and do not require expense of separate vertical aerial fitting.	Necessary for both point and "sense" bearings. Not incorporated in frame design necessitating additional expense of a separate vertical aerial.
Induction	Not very sensitive to induction owing to— (A) Flexibility allowing frame to be placed in induction free positions. (B) Perfect and cheap screening between frame and receiver.	Very sensitive to induction owing to— (A) Non-flexibility of fitting. (B) Difficulty of perfect screening between frame and receiver.

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RADIO TELEPHONY DISTORTION

A particular type of distortion occurring in Short Wave telephony and telegraphy reception, involving a partial disappearance of modulation with retention of carrier signal has been noticed on many short wave stations, especially when the receiver is within the skip distance of the transmitter.

An attempt to explain this phenomenon is given in the following article.

Some correspondence bearing on this subject was published in our last issue.

MOST of the causes of distortion in radio Telephony have been discussed from time to time, under the headings of "frequency distortion" "selective fading of the side bands and carrier," etc., but there is one effect which has not received the attention it deserves, and which it is proposed to discuss in the following article.

It has been noticed that in certain conditions, the carrier of a telephone station is strongly received but with very little or no trace of modulation.

This has led, in certain cases to accusations of insufficient modulation from the receiving end, which have been indignantly repudiated by the sender. Such a state of affairs may well be ignored by the casual observer who does not know what exact amount of modulation to expect, but an experienced observer can detect the effect at once, and sufficient data has been collected to leave one assured that it is genuine. The effect is most marked within the skip distance. As an example, the Broadcast Station 5 S.W. at Chelmsford working on a wavelength of 25 metres received at Somerton gave a measured carrier so strong that in normal conditions strong modulation should have been heard, yet the modulation was inaudible except for faint sounds at rare intervals. A similar effect has been observed in telephone transmission from aeroplanes where, in the skip distances, strong carrier waves without modulation are often reported.

The following tentative explanation is offered:—If a single short impulse is sent out by a transmitter, oscillographic and facsimile reception methods show in general the existence of more than one impulse at the receiver. Sometimes as many as four to five separate echoes following at intervals of a millisecond or so are received, and in some cases where scattering is present, a single short impulse may be received as a prolonged signal spread over an interval of 20 milliseconds or so. The later echoes or scattered signals owe their delay to having travelled by a longer path, the various possible paths being represented diagrammatically in Fig. 1 as ricochets between the earth and the Heaviside layer. When scattering is present, the signals may follow irregular paths from scattering centres, distributed in the Heaviside layer as illustrated in Fig. 2, where BOR represents the paths of the scattered signal from a Beam Station at B, say, BR being the direct signal.

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Whatever the mechanism may be that causes them, these echoes undoubtedly exist. Consider now what will happen if a train of dots of frequency 500, say, is sent out, and echoes of $\frac{1}{1,000}$ sec. delay are prevalent. The curve A (Fig. 3) will represent the first signal, the curve B in which the dots exactly fill up the spaces in A will represent the second signal. If the A and B signal are of equal intensity, the envelope of the sum of the two will be a straight line, and on reception and rectification, the received detector current (except perhaps for the momentary effects of change of phase at the junction of the A and B—dots) will be a constant current, and there will be no modulation although the carrier is strong. Although this illustration represents an extreme case, it requires but little consideration to see that in general where there are many echoes, the modulation will be reduced relatively to the carrier by the filling up of the spaces in the transmission. An effect of almost exactly this nature has been observed when listening at Chelmsford to the local Beam stations which are so close as to be within the skip distance. In such cases it is very often observed that when listening to dots at high speed the signal is almost completely blurred into a nearly continuous dash.

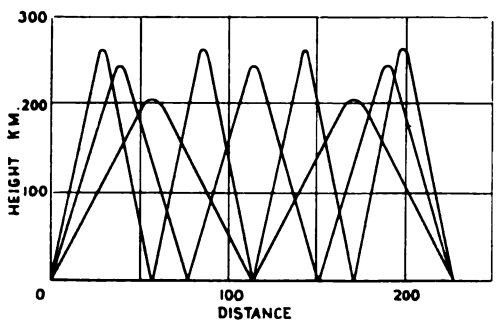

FIG. 1.

The effect is most marked in the skip distance because the relative intensity and delay of the echo signals are greatest in such conditions. It is perhaps not quite so easy to see what happens when the direct and echo signals do not fit in so exactly as specified above in the simple explanation. The attempt to analyse the effect by the consideration of the side bands appeared at first sight to contradict the foregoing reasoning. Thus in a scattered field, for instance, where this effect is most marked, the electromagnetic forces are made up of the sum of a number of more or less equal contributions of random phase. In accordance with Rayleigh's Theorem the energies of each component have to be added, not the amplitudes, and the final amplitude is the square root of the sum of the squares of the contributing amplitudes, *i.e.*,

$$\overline{E} = \sqrt{\overline{E_1^2} + \overline{E_2^2} + \overline{E_3^2} + \ldots \text{ etc.}}$$

In the same way we take the energies of the side waves, add them and take the square root to obtain the resultant side wave amplitude, *i.e.*,

$$\overline{E^1} = \sqrt{\overline{E_1^{12}} + \overline{E_2^{12}} + \ldots}$$

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Now since in transmission, except for accidental phase interferences,

$$\frac{\overline{E_1^1}}{E_1} = \frac{E_2^1}{E_2} \quad . \quad . \quad . \quad = K$$

the ratio of the transmitted side wave, to transmitted carrier, therefore $\frac{\overline{E^1}}{E} = K$ on the average.

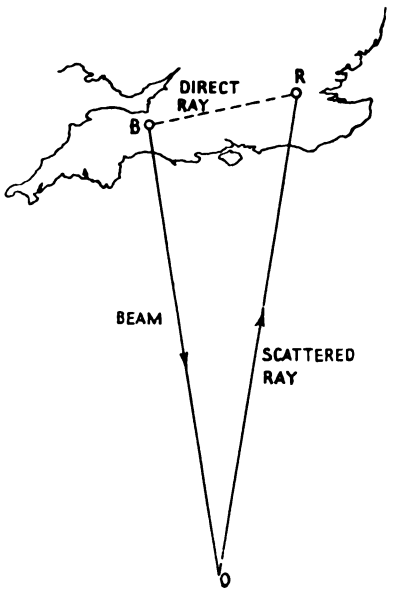

FIG. 2.

It would therefore appear that there is no average reduction of the side waves relative to the carrier ; *i.e.*, the processes of transmission, scattering, etc., alter the carrier and side waves equally leaving the ratio constant, and since the depth of modulation depends on this ratio, it, apparently, remains constant.

The contradiction is cleared up if we take account of the relative phase of the carrier and side bands.

Strictly speaking the phase of the side bands $2\pi (v_1 - v_2)\ t + 0$, or $2\pi (v_1 + v_2)\ t + \theta_2$ of a simple sine modulated wave (where v_1 is the carrier frequency and v_2 is the modulation frequency) does not differ from the phase of the carrier $2\pi v_1 t$ by a constant amount but varies through a whole cycle of 360° in a period of the modulation.

But if we combine the two side waves

$$\frac{K_1}{2} \sin \left\{ 2\pi(v_1 + v_2)t + \theta_1 \right\} + \frac{K_1}{2} \sin \left\{ 2\pi(v_1 - v_2)t + \theta_2 \right\}$$
$$= K_1 \sin \left\{ 2\pi v_1 t + \frac{\theta_1 + \theta_2}{2} \right\} \cos \left\{ 2\pi v_2 t + \frac{\theta_1 - \theta_2}{2} \right\} \quad . \quad . \quad (1)$$

and compare this with the carrier wave $\sin (2\pi v_1 t)$, say, the high frequency component of (1) $\sin \left\{ 2\pi v_1 t + \frac{\theta_1 + \theta_2}{2} \right\}$ has a definite phase relation or phase difference $\frac{\theta_1 + \theta_2}{2}$ from the carrier wave. When we spoke of the phase difference between carrier and side waves we implied this quantity. In a scattered field we have assumed that this phase is a random quantity.

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This is justified if we consider the mechanism of scattering ; the phase on any path is $\int \frac{ds}{v}$ and this varies for the different paths and different frequencies, and since the paths are randomly distributed, the individual and resultant phases will also be randomly distributed.

Again, according to (1) the phase of the modulated envelope is $\frac{\theta_1 - \theta_2}{2}$, and, therefore, $\frac{\theta_1 - \theta_2}{2}$ will represent the delay times of one of the modulated signals, which we have seen from observation vary at random in a scattered field up to

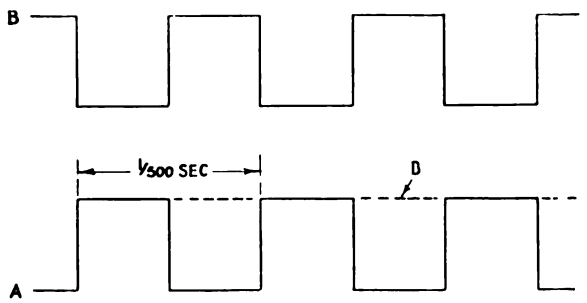

FIG. 3.

20 milliseconds or more. We must therefore, as a matter of observation, consider $\frac{\theta_1 - \theta_2}{2}$, and therefore θ_1, θ_2, and $\theta_1 + \theta_2$ a random quantity. The resultant of side bands and carrier for one modulation frequency v_2 will be

$$Z = \sin 2\pi v_1 t + K_1 \sin\left(2\pi v_1 t + \frac{\theta_1 + \theta_2}{2}\right) \cos\left(2\pi v_2 t + \frac{\theta_1 - \theta_2}{2}\right)$$

Let $$2\pi v_1 t + \frac{\theta_1 - \theta_2}{2} = X \text{ say, and } \frac{\theta_1 + \theta_2}{2} = \theta$$

Then we have $$Z = \sin(2\pi v_1 t) + K_1 \sin(2\pi v_1 t + \theta) \cos X$$

Expanding the latter term we get

$$\sin 2\pi v_1 t\,(1 + K_1 \cos\theta \cos X) + \cos 2\pi v_1 t\,(\sin\theta \cos X)$$

and the modulated amplitude is therefore

$$\sqrt{(1 + K_1 \cos\theta \cos X)^2 + K_1^2 \sin^2\theta \cos^2 X}$$
$$= \sqrt{1 + K_1^2 \cos^2 X + 2K_1 \cos\theta \cos X} \quad *$$

* Mr. Ladner has used a Vector method to show these results.

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This gives a modulation envelope which, when $\theta = 0$ or $n\pi$, is of the usual form $(1 \pm K_1 \cos X)$, but which when $\theta = (n + \frac{1}{2})\pi$ is $\sqrt{1 + K_1^2 \cos^2 X}$.

In the form (1) the envelope lies between the limits $1 + K_1$, and $1 - K_1$, and in form II between 1 and $\sqrt{1 + K_1^2}$, which when K_1 is small represents a very small variation. The curves in the figure show the modulated envelopes in the cases for $K_1 = \frac{1}{2}$. They indicate that where the side waves are misphased 90° (in the above sense), the modulation is very largely reduced, and will be so for all values of θ not 0 or $n\pi$, *i.e.*, for all cases of misphasing from the normal. The resultant modulation to be expected where θ is a random quantity is always less than the normal modulation transmitted.

If all values of θ are equally probable we obtain an "average modulation" curve of the form

$$Y = \frac{1}{\pi}\int_0^{\pi} \sqrt{1 + K_1^2 \cos^2 X + 2 K_1 \cos X \cos \theta}\, d\theta$$

We will suppose K_1 is small, as it nearly always is for each particular modulation frequency

Then if $a = 1 + K_1^2 \cos^2 X = 1 + K_1^2 \cos^2 \left(2\pi v_2 t + \frac{\theta_1 - \theta_2}{2}\right)$

$$b = 2K_1 \cos X$$

then $$Y = \frac{a^{\frac{1}{2}}}{\pi}\int_0^{\pi} \sqrt{1 + \frac{b}{a}\cos \theta}\, d\theta$$

where $$\frac{b}{a} = \frac{2K \cos X}{1 + K^2 \cos^2 X}$$

and is always < 1, and small if K_1 is small.

We may expand the square root and obtain

$$Y = \frac{a^{\frac{1}{2}}}{\pi}\left\{\int_0^{\pi} d\theta + \int_0^{\pi} \frac{1}{2}\frac{b}{a}\cos \theta d\theta - \int_0^{\pi} \frac{1}{2}\cdot\frac{1}{2}\frac{1}{1.2}\frac{b^2}{a^2}\cos^2 \theta d\theta + \text{etc.}\right.$$

and integrating

$$Y = a^{\frac{1}{2}}\left(1 - \frac{1}{16}\frac{b^2}{a^2} + \text{etc.}\right)$$

which to the first approximation is $a^{\frac{1}{2}}$, *i.e.*, the average modulation is

$$a^{\frac{1}{2}} = \sqrt{1 + K_1^2 \cos^2 (2\pi v_2 t + \theta')}$$

which is always small compared with the normal modulation.

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Thus, for instance, if K_1 is 10 per cent., $a^{\frac{1}{2}}$ varies between 1 and $1 + \frac{1}{200}$ with an effective modulation of $\frac{1}{4}$ per cent., *i.e.*, a very great reduction of modulation.

It therefore would appear that in a scattered field, where the side waves may be random phased with respect to the carrier, the modulation is distorted (see Fig. 4) and very much reduced.

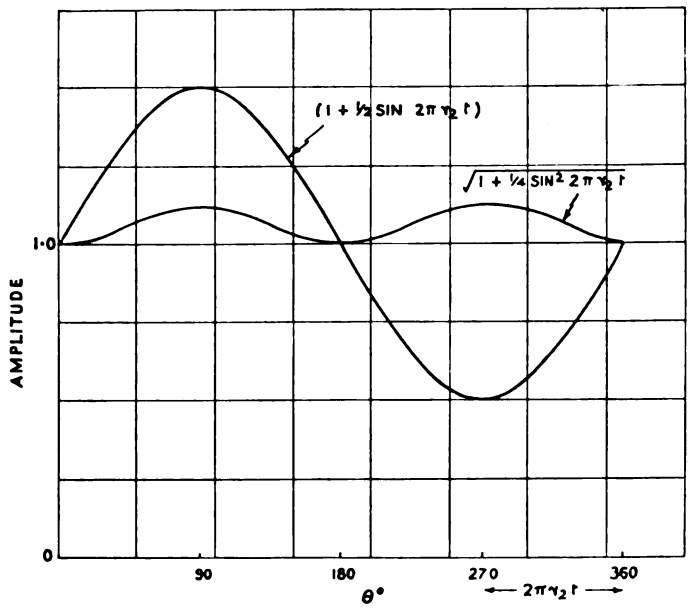

FIG. 4.

It might perhaps be thought that the side band method of treatment was unnecessary in view of the clear picture of the smoothing of the modulation given in the original description, but apart from the added satisfaction of explaining the effect by two methods, it brings to light a fact which is not obvious in the former explanation, viz., that single side band transmission with suppressed carrier will eliminate this effect.

It is clear that if a single side band only is transmitted then whatever its phase may be, it produces a fully modulated tone in beating with the carrier supplied at the receiving end.

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Thus

$$\text{Side band} = K E \sin (2\pi (\nu_1 + \nu_2) + 0)$$
$$\text{Heterodyne } E \sin (2\pi \nu_1 t)$$

which varies in amplitude from $E + K E$ to $E - K E$ according as the two are in phase or out of phase, *i.e.*, the modulating amplitude has a range $2KE$, and is fully modulated.

Single side band suppressed carrier methods will have the advantage of eliminating this type of distortion and reduction of modulation. Such methods, though already attempted on short waves, have been attended with great difficulty, since the frequency separation of the side waves from the carrier is such a small percentage of the carrier frequency that any lack of stability of the latter will carry the frequencies outside the filter bands and fail to eliminate the carrier and one side band.

Improvements in frequency stability of transmitters will probably enable such methods to be used, and will not only eliminate the effect discussed, but also the more normal type of fading dependent on the product of the carrier and side band intensity.

T. L. Eckersley.

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LINE TRANSMISSION UNITS

The Technical Editor of THE MARCONI REVIEW *publishes below some correspondence relating to an article entitled "Notes on Transmission Measurements" which appeared in* THE MARCONI REVIEW, *No. 24, for September,* 1930.

Attention is directed to the last letter, in which Mr. C. E. Rickard weighs the relative pros and cons of the use of transmission units when discussing wireless circuits, and in particular to the table given therein, which should prove of especial interest to the wireless engineer as it provides a simple method of correlating transmission units and voltage or current ratio measurements.

"Sir,—The advocates of line transmission units are rapidly submerging the wireless engineer with their ideas of measurement and one is tempted to ask whether the line engineer's angle of view is sufficiently like that of the wireless engineer to make the former's system suitable for high frequency work.

The article in the September number of THE MARCONI REVIEW entitled 'Notes on Transmission Measurements,' sets out the telephone engineer's viewpoint to some extent and provides food for thought. For instance, the writer of the article remarks that 'it should be clearly understood that all units used for the measurement of transmission characteristics are relative.' This is a somewhat definite statement and conveys the fact that the relative measurements are of more importance in transmission work than the absolute measurement of power at any point. It may be clearly understood by the telephone engineer, but to the average wireless man the point is not at all obvious and on the face of it a relative measurement is not of particular interest in itself.

Two amplifiers may each have a gain of 50 DB, but this fact in itself conveys nothing. One amplifier might be contained inside a cigar box, and cost £1, whereas the other might require a building to house it and cost £10,000.

The truth is that the line engineer is involved to such an extent in closely inter-connected circuits whose levels are maintained at a fairly constant value, that it is relative values he talks in, but although he talks in these relative values, he has at the back of his mind all the time an input of definite value which is implied, if not actually stated.

Further his apparatus is always matched to a line of known constants both as regards input and output. In fact, it is the line which is the controlling factor in the system and it is because the terminations are always the same that a relative system becomes useful.

In high frequency work we have no lines to match, our input impedances are various (and in many cases difficult to measure), we have a great variety of output impedances, in very few cases do input and output match, and in consequence it becomes necessary to specify actual power output and input volts. Because of this, because the terminations are different and because of the necessity for stating actual figures, it makes the relative measurement of little interest, and it would be a great pity for us to adopt wholesale the telephone engineer's terminology, particularly as the units do not appear to be of too stable a character. For if the table given on page 19 is studied, it will be seen that the line engineer has had a good many attempts to find a suitable unit of relative loss (or gain) and it seems unfortunate that the most recent conference on the subject should still leave the matter ambiguous, that is, if the quotations given set out the findings of the C.C.I.

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Once it is realised that the only true measure of loss (or gain) is one of power, then a unit dealing in relative loss (or gain) should be a power ratio. The voltage or current ratio is completely meaningless (unless qualified), besides which it leaves the use of the unit 'bel' ambiguous, and the retention of such additional units having the same name appears to the writer to be a confession of loose thinking.

The ambiguity is carried still further by allowing the individual to fix his own zero level, instead of making a definite ruling on the matter and bringing all people into line. If it is agreed that zero level is a reference point, then for the sake of clearness one would expect that reference point to be fixed, even though that fixing is not wholly suitable to everyone's taste.

In some ways it would be logical to put frequency on a relative basis since the discrimination of tone is logarithmic, in fact, it has been suggested, but I cannot visualise the wireless man being so misguided as to fix zero level at any point that suited him, although to one section 10^7 would be a convenient zero level, and to another 10^4; the broadcast engineer would be torn between two desires, to have one level at about 10^6 and another at 10^3.

A further limitation to the present decibel assessment is that it can only be applied to a proper amplifier, that is, an amplifier which is working sinusoidally, but in high frequency transmission work many of our amplifiers are not working sinusoidally.

No doubt the bel will in due course find its own level in the scheme of things (and in its way it is of value), but at the moment being somewhat new, what might be called the percentage method of thought is in danger of being overdone and one finds the bel in peculiar places. Quite recently a foreign government called for tenders for telephone switchboard apparatus having sufficient switches such that the ratio of calls lost to what is known as 'busy hours' was not greater than such and such a figure. One manufacturer in quoting expressed the ratio of calls lost to 'busy hours' in decibels.

These observations are made, not in the spirit of criticism, but because of the close link that is developing between the line and wireless engineer it is essential for each to understand the other's language and a little expansion of the article in question would be of general interest to the wireless man.

Chelmsford College. A. W. LADNER.

December 3rd, 1930."

"Sir,—I beg to reply to the points raised by your contributor as follows:—

1. An objection is raised to the statement in THE MARCONI REVIEW that all units used for the measurement of transmission characteristics are relative, and this statement is taken to mean that relative measurements are of more importance than absolute measurements. The next paragraph in the Review, however, shows that an absolute measurement of power is obtainable in the system by making a measurement of level. The great advantage inherent to the use of a relative measurement lies in the fact that a ratio of input to output may be specified together with a maximum output level and this information completely defines the operational ability of the apparatus in question, except with regard to the matter of phase shift. In common with any other piece of electrical apparatus it is essential that its impedance be suitable for the circuit in which it is connected, for even motors, lamps, stoves, etc., have their impedance arranged to suit the existing conditions.

2. The critic states that 'two amplifiers each may have a gain of 50 DB, but

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this fact in itself conveys nothing : one amplifier might be contained inside a cigar box and cost £1, whereas the other might require a building to house it, and cost £10,000.'

This is true ; it is essential also to state the maximum input or output level, and the frequency range over which it is designed to operate.

3. It is also true that the line engineer talks in relative terms, while implying a definite reference value.

Next, it is a fact that line apparatus is matched in a specific manner to a line of known constants both as regards input and output. Is not this so with every piece of electrical apparatus, where effective and efficient operation is desired? It is, however, wrong to assume that it is because the terminations are always the same that a relative system becomes useful ; the terminations are, in fact, not always the same. The fact that the input and output impedances may be unequal does not preclude the possibility of measuring the loss or gain in the system of Line Transmission Units which are in general use.

4. It is stated that the decibel assessment of gain can only be applied to an oscillator operating with a sinusoidal input, whereas most transmission (presumably radio transmission) work amplifiers operate on the flick impulse system. But it would appear that a radio amplifier may be treated exactly like a telephone line amplifier. Such an amplifier is required to operate over a large range of frequencies and with peculiar and ever-changing waveform. The gain of an amplifier is measured at one or more frequencies within its operating range with a sinusoidal input, and provided the maximum amplitude of the potential applied to the input under working conditions is not sufficient to bring about distortion, the gain will remain substantially the same no matter what the waveform may be, so long as it contains no frequencies outside the specified range. If therefore, the maximum input or output level be stated as well as the gain or loss over a specified frequency range, the measurement becomes complete except for the phase shift.

5. The units employed in Line Transmission Measurement are not unstable as suggested by the critic. This table on page 19, together with the context, was drawn up in order to show the history of the development of the present Line Transmission Units, and to show how they are related to their predecessors. The present state of the units is really not ambiguous, for as stated on page 15, 'two new units, the Bel and the Néper were recommended as the basis of all future communications measurements.'

6. It is stated in the criticism that 'once it is realised that the only true measure of loss (or gain) is one of power, then a unit dealing in relative loss (or gain) should be a power ratio. The voltage or current ratio is completely meaningless (unless qualified), besides which it leaves the use of the unit "bel" ambiguous, and the retention of such additional units having the same name appears to the writer to be a confession of loose thinking.'

The first sentence is perfectly correct as is shown on page 17 of the article in question. The second sentence is also correct inasmuch as a statement of voltage or current ratio is useless unless the input and output impedances are the same. The second part of the latter sentence is incorrect since the use of the unit 'bel' is not ambiguous and it is incorrect to state that 'the retention of such additional units, etc., is a confession of loose thinking,' because there are no additional units having the same name, although the decibel was originally known as the Trans-

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mission Unit, *i.e.*, two names for one unit, however, the Transmission Unit is now obsolete. Possibly the critic refers to the use of the $\frac{V_1}{V_2}$ and $\frac{I_1}{I_2}$ ratios as 'additional units with the same name.'

7. Although different people are in the habit of fixing their own zero level, it is believed that an official zero level of 1 milliwatt has been fixed for testing purposes.

8. The measurement of frequency in terms of a zero level although possible is not at all to be desired and the objections raised by the critic are entirely endorsed by the writer.

As is the case with most new things which have a popular appeal, the Line Transmission Units of Measurement may perhaps be applied to unsuitable cases by persons who are not familiar with their limitations, but it is considered that where a sympathetic study of the uses and applications of the system is made, a great advantage will be found to accrue in the matter of ease of calculation and simplicity of description of the operational characteristics of apparatus.

It is hoped that the foregoing remarks may help to elucidate the terms and the line of thought involved in the system under review.

Marconi House, Strand, W.C. 2. O. S. PUCKLE.
January 22nd, 1931."

"Sir,—At first sight, I thought that the fulfilment of your request for me to round off the interesting discussion between two of your contributors on the subject of the transmission unit would be as simple a task as it is congenial. I find, however, on going more closely into the articles in the September and the present issue that the two authors have left little to be said.

In considering their different points of view I think that in order to get the right perspective we require to study the *raison d'être* of the transmission unit and the objective of the telephone engineer as compared with that of the radio engineer or any other scientist to which the 'decibel' might be of interest.

From the point of view of the transmission of electrical energy it might fairly be said that the telephone engineer is single-minded and that his great object in life is to maintain a certain level of energy, that is to say, his purpose is to transmit the equivalent energy of the human voice, whose level for normal conversational purposes is definite and moderately constant, over a landline and deliver it at the other end at the same intensity. A convenient level of intensity has been established arbitrarily as 1 milliwatt delivered into a 600-ohm terminal impedance, and is known as 'zero' level.

In the early years of telephone development the telephone engineer was not greatly concerned with transmission losses because his distances were then relatively small and he was concerned mainly with overhead lines, but so soon as development demanded transmission through cables, or over long landlines, the problem of losses in transmission became very evident. At the outset the workers in the telephone industry found it convenient to measure the losses in terms of the 'mile of standard cable,' and by means of exponential formulæ the losses on lines or cables could be reduced to a common basis. Three points of interest emerge from this, which differ from the ordinary engineer's standpoint, viz. :—

(A) that the telephone engineer deals with an average level of power of the order of one milliwatt ;

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(B) his thoughts are concerned with losses rather than efficiencies ; and
(C) his efficiencies are 'exponential' whereas the power engineer's losses are additive.

Thus, if the loss of energy in a telephone transmission line one mile long is 10 per cent., the efficiency or ratio of output to input at the end of 4 miles of the line will be $\left(\frac{9}{10}\right)^4$ whereas, if the C^2R loss over a power line one mile long is any given amount, the loss over 4 miles of line will be four times that quantity.

So soon as the telephone engineer had at his disposal means of making good his losses by means of repeaters, he became concerned with relative gains, as well as relative losses. The relationship between the gain of the repeater and the loss on the line is clearly very intimate, the objective being to bring back the weakened speech signal to normal value, or to increase it to some extent above normal, so as to make up for further losses in the next section of line or cable.

But here came the difficulty ; whereas the telephone engineer could measure his losses in terms of miles of standard cable, it would have been incongruous to measure the gain of his repeater in the same units.

The natural development was therefore to adopt a unit, known as the transmission unit, which could be equally well applied to losses in cables, or gains in amplifiers. The need for such a unit was so obvious that the basic T.U. adopted by the Bell Company was accepted internationally under the name of 'decibel' or 'db' and to satisfy the purists who felt that the new unit should be based on the naperian logarithm, since basic calculations are made in terms of powers of ϵ, the alternative units of 'decineper' and 'neper' were also established.

The adoption of an 'exponential' unit has particular value in telephone engineering, not only because the line efficiencies are exponential in relation to their length, but also because the gains of amplifiers are exponential in relation to the number of stages used, the losses in filters are exponential in relation to the number of cells and, last but not least, the appreciation of relative acoustic energy by the human ear is exponential in character. Hence to calculate losses over a given number of miles of line or cable, or the gain of an amplifier, the telephone engineer has merely to subtract or add the indices, *i.e.*, to say logarithms of his exponential ratios, or in other words, to add or subtract the number of decibels loss or gain.

Thus it may be said that the so-called transmission unit, or exponential unit of ratio, filled a long-felt want.

Let us now make quite certain what is this unit. According to definition we have, when comparing relative input and output energies, or vice versa,

$$\text{Number of bels} = \log_{10}\frac{P_1}{P_2}$$

$$\text{Number of decibels} = 10\log_{10}\frac{P_1}{P_2}$$

$$\text{So that 1 decibel} = \text{ratio } \frac{10^{0.1}}{1}$$

$$\text{And 1 Bel} = \text{ratio } 10^1 = 10:1$$

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Similarly when comparing amplitudes we have—

$$\text{Number of nepers} = \log_\epsilon \frac{V_1}{V_2} = \log_\epsilon \frac{I_1}{I_2}$$

$$\text{Number of decinepers} = 10 \log_\epsilon \frac{V_1}{V_2} = 10 \log_\epsilon \frac{I_1}{I_2}$$

$$\text{So that 1 decineper} = \text{ratio } \frac{\cdot 2718 3}{1}$$

$$\text{And 1 neper} = \text{ratio } 2 \cdot 7183/1.$$

Thus, when we say that an amplifier has a gain of say 20 decibels or 2 bels, we mean that the ratio of $\frac{\text{output}}{\text{input}} = 10^2 = 100$. Similarly, if we wish to compare amplitudes, such as the ratio of $\frac{\text{output signal strength}}{\text{input signal strength}}$ in an amplifier, we may define the gain as so many nepers.

It is obvious that with the foregoing we have a convenient recognised scale of definite ratios and as such there seems no reason why we should not make such use of it as may seem fit and proper.

But so soon as we begin to use it we immediately realise its limitations, and that a statement of gain or loss in decibels, *i.e.*, to say the use of a ratio, conveys an incomplete impression on the mind unless it be accompanied by a reference point or level. When an engineer makes a statement that an amplifier has a gain of 10 decibels, or a cable has a loss of 10 decibels, the information conveyed is simply a ratio, that of output to input. We cannot compare two amplifiers each having a gain of say 60 decibels unless we know either the input or the output, *i.e.*, to say some reference point ; we could not compare a receiving amplifier with a power amplifier. Still, all receiving amplifiers deal with a received signal of the order of microvolts, and their outputs are usually of the order of milliwatts, that is to say, they deal with feeble currents and powers where losses or gains of energy have no great financial consequence as regards loss or gain of power. For example, a telephone engineer can contemplate losing 99 per cent. of his available energy with equanimity, knowing that he can multiply what is left by 100 at little cost in fuel or power. But, should a radio engineer talk of a power amplifier having a gain of say 50 decibels, unless the output of the amplifier be given in kilowatts, the information would be of little value. Or take the case of short wave feeders, the receiving engineer can contemplate a loss of one decibel between aerial and receiver without turning a hair, but the engineer responsible for the transmitting station design cannot but be greatly concerned with such a loss in a transmitting aerial feeder. To the receiving expert the loss of one decibel is only just perceptible by the human ear, a matter of little or no importance, but to the transmitting expert one decibel may mean several kilowatts, which have to be provided and paid for. It follows, therefore, that the use of the 'decibel' and allied units is peculiarly adapted for the comparison of weak or negligible power values, which may vary exponentially, that is to say, in enormous proportions and yet at their maximum be measured in fractions of a watt. Particularly as regards telephony and acoustics, where the power involved is negligibly small, and varies as regards its manifestations in accordance with an exponential law, the decibel unit is a very valuable measure which conveys relative values to the human brain, in a more

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easily comprehensible way to the trained mind than the mere statement of a large numerical ratio. When the reference power exceeds a few watts, the question of the power involved becomes vital, and one cannot readily assimilate ratios of power except as 'efficiencies,' *i.e.*, to say percentages of output to input. In such cases the loss of even a small percentage is of importance—so that the measure of such losses by the transmission unit would be in small fractions of a decibel.

It follows that where we have to deal with large variations or ratios of comparatively small input and output power, such variations being exponential in character, the decibel gives us a very valuable means of conveying and assimilating information, especially when accompanied, as it must be, with a reference level or datum. On the other hand, the use of the decibel when dealing with large power inputs and outputs, fails to convey in an explicit manner a proper appreciation of the powers involved, and a statement of efficiency ratio is then better expressed in the normal way as a percentage.

For those engineers who are not in daily contact with the elusive decibel, the following tips may be found useful as a means of rapid assessment of the numerical ratio of a gain or loss expressed in decibels without reference to tables. It is only necessary to commit to memory two key values, viz., 10 decibels corresponds to the ratio 10/1 and one decibel corresponds very approximately to the ratio 5 to 4 or 1¼ to 1, or 1 to ·8. Starting from 10 db. downwards, we can at once write down the db. table of ratios thus :—

			True value.
10 decibels	= 10 to 1		10
9 ,,	= 10 × 4/5	= 8 to 1	7·943/1
8 ,,	= 8 × ·8	= 6·4 to 1	6·31/1
7 ,,	= 6·4 × ·8	= 5 to 1	5·012/1
6 ,,	= 5 × ·8	= 4 to 1	3·981/1
5 ,,	= 4 × ·8	= 3·2 to 1	3·162/1
4 ,,	= 3·2 × ·8	= 2·5 to 1	2·512/1
3 ,,	= 2·5 × ·8	= 2 to 1	1·995/1
2 ,,	= 2 × ·8	= 1·6 to 1	1·585/1
1 ,,	= 1·6 × ·8	= 1·25 to 1	1·259/1

From this table we can now write at once—

11 decibels	=	12·5 to 1
12 ,,	=	16 to 1
13 ,,	=	20 to 1
14 ,,	=	25 to 1
24 ,,	=	250 to 1
34 ,,	=	2500 to 1 and so on,

and it is of course easy to remember that 20 decibels = 10^2 = 100; 30 decibels = 10^3 = 1,000, etc.

The above values while only approximate are quite near enough for all practical purposes.

C. E. Rickard.

Marconi House,
Strand, W.C. 1.
March 11th, 1931."

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MARCONI SHORT WAVE TRANSMITTER
TYPE T.N.19

In THE MARCONI REVIEW *for July, 1930, an article appeared describing the Type S.100 series of short wave transmitters. This series has recently been modified, and is now available under the type-title of T.N.19.*

The T.N.19 series of transmitters whilst retaining all the desirable points of the S.100 series, represent a distinct improvement over the earlier type, as will be seen from the following description.

THE Marconi Type T.N.19 transmitters have been designed as compact low power short wave telegraph or telephone sets, suitable either for permanent installation in submarines, vehicles, etc., or at a fixed point. The waverange of the transmitter is 15/75 m., and the sets are available in the following combinations :

T.N.19A Complete telegraph-telephone driven transmitter.
T.N.19B Driven telegraph transmitter.
T.N.19D Modulator Unit for use with T.N.19B.

A photograph showing the T.N.19A driven transmitter arranged for either telegraphy or telephony is given in Fig. 1. It will be seen to consist of two separate units, that on the left being the modulator unit, and that on the right the main transmitter unit incorporating the drive and magnifier circuits.

Telephone Modulator Unit.

A circuit diagram of the Modulator System is given in Fig. 2, and the unit consists of a screened brass container 26 inches high by 12 inches wide by $12\frac{3}{4}$ inches deep.

The purpose of this modulator panel is to provide :—

(A) Telephony.
(B) I.C.W. telegraphy on one of three chosen note frequencies.

The valve used in this panel is one M.T.12A type transmitting valve which is connected to a change-over switch shown on the bottom right-hand corner of the modulator unit. With this switch to the right, *i.e.*, in I.C.W. position, the M.T.12A valve is connected in circuit as a low frequency oscillator, the valve being thrown over to a tuned low frequency oscillating circuit instead of to the speech choke and microphone transformer. By means of a single-pole three-point note selector switch, shown in Fig. 1, placed centrally between the meters on the panel, the period of the low frequency oscillating circuit can be modified allowing for a transmission of I.C.W. on one of three different frequencies.

The measuring instruments shown on the modulator unit are the filament voltmeter on the right of the note selector switch, and the feed milliammeter to the left of the switch. Directly below the note selector switch is the filament rheostat control for the modulator valve.

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A three-contact solenoid relay working from the filament supply is situated inside the modulator unit to the left of the valve. This relay provides a means of remotely controlling the change-over from C.W. telegraphy to telephony or I.C.W. working. When transmitting on telephony the valve in the modulator unit is switched over to the speech choke and microphone transformer. This is done by the Telephony/I.C.W. switch shown in the bottom right-hand corner of the modulator unit.

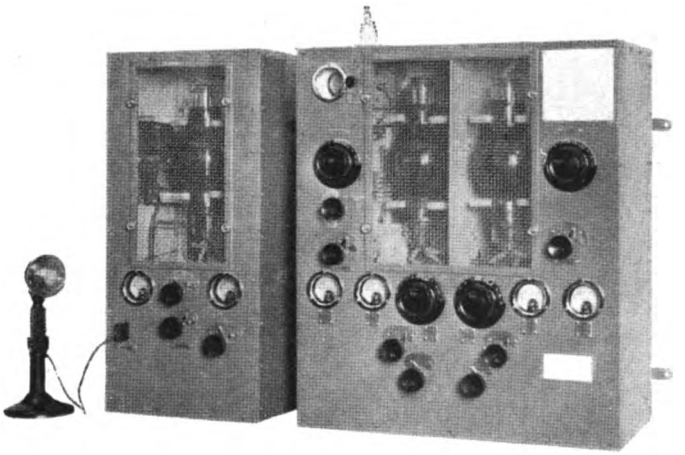

FIG. 1. *T.N.19a Transmitter.*

Transmitter Unit.

This, as shown on the right-hand side of Fig. 1, is completely enclosed in a metal box with all controls and measuring instruments on the front of the panel. All repairs can be effected from the front of the unit the design being such that the front metal panels can be easily removed.

It will be seen from the circuit diagram given in Fig. 3, that the two M.T.12A valves are used, one for the drive and one for the magnifier circuits. The H.T. supply of 2,500 volts D.C. is taken on to the magnifier anode direct, the drive valve being fed through two 30,000 ohm resistances in parallel.

The whole of the drive portion of this transmitter is shown in the right-hand portion of the Transmitter Unit, while the magnifier valve and its associated circuits are shown in the left-hand portion of the Transmitter Unit. There is a definite screening partition between the two portions, *i.e.*, Drive and Magnifier.

The wave changes of the drive circuits are effected by means of a special inductance tapping switch and a slow motion variable condenser control, shown on the right-hand portion of the transmitter unit. A small variable condenser is used as a means of coupling the drive circuit to the grid of the magnifier valve.

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The magnifier circuit wave changes are effected by means of a vernier condenser and an inductance switch similar to those used on the drive portion. These controls are shown on the left-hand side of the Transmitter Unit.

A neutrodyne condenser has its control situated on the front of the Transmitter Unit, to the left of the coupling condenser control knob.

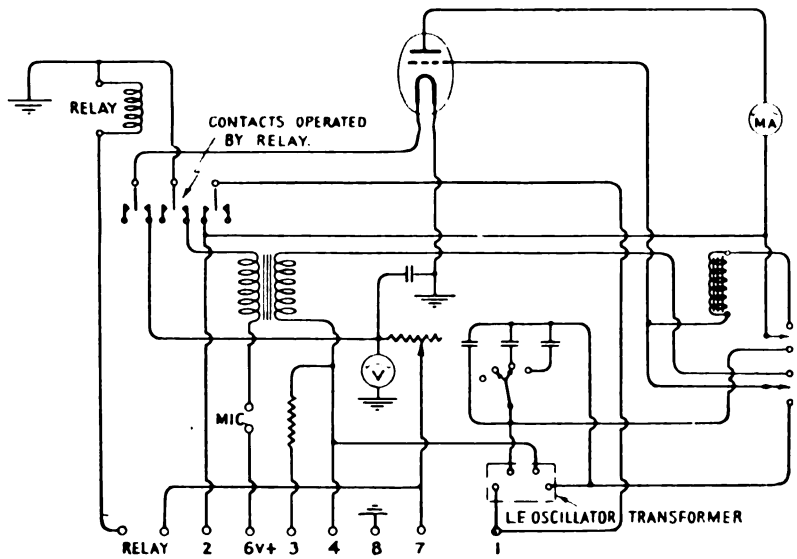

FIG. 2.

In addition to this neutrodyning condenser, the following are supplied for the purpose of neutrodyning :—

(A) An H.T. switch near the bottom of the unit.

(B) A Hot Wire Ammeter.

(C) A Push Switch fitted to the upper left hand of the Transmitter Unit.

An aerial tapping switch with five selected positions is provided and fitted below the magnifier tuning condenser. This switch is intended to provide a sufficient variation of coupling of the transmitter to the aerial system.

Each of the drive and magnifier valves is provided with a filament rheostat, and a filament voltmeter with change-over switch enables readings of the filament voltage of each valve.

The method of neutrodyning is as follows. With the aerial disconnected and the circuits, both drive and magnifier, adjusted in accordance with the wavelength table shown on the top right-hand corner of the magnifier is pressed. H.T. from the machine is then applied and on pressing the transmitting key the drive valve

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should oscillate. Provided the wavelength of the drive valve is correct, and this can be checked by the wavemeter supplied, the magnifier circuits should then be brought into correct tuning with the drive circuits by adjustment of the magnifier tuning condenser.

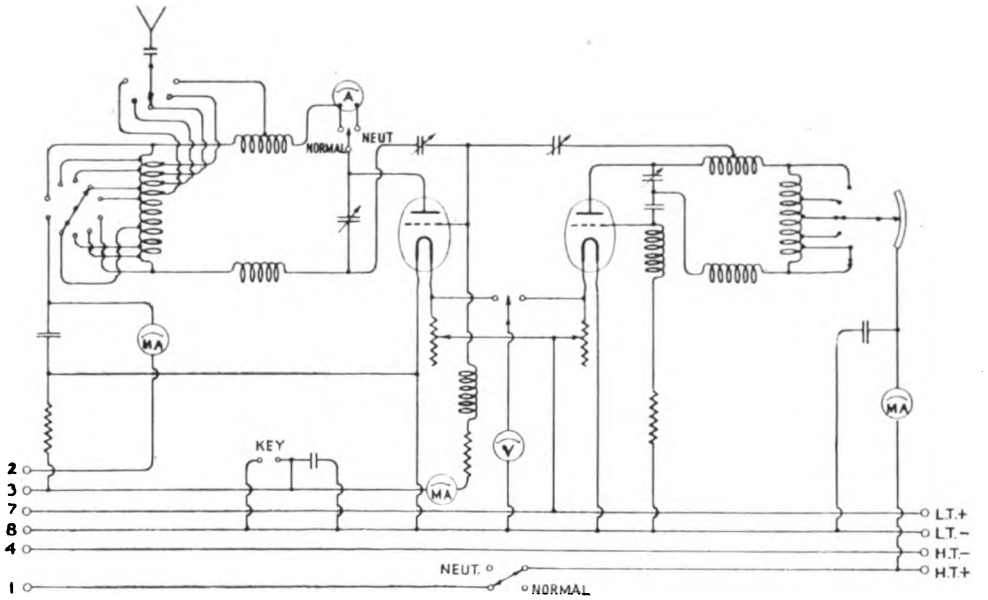

FIG. 3.

The neutrodyne condenser is now adjusted so that the reading on the meter is zero. In this condition the transmitter is now balanced for the particular wavelength being transmitted, and the connections should be made for normal working Transmission on pure C.W. can now be carried out in the normal way.

The method of keying consists of simultaneously interrupting the grid filament circuit of both the magnifier and drive valves, and also the negative of the high tension to earth.

Power Supply.

The power supply, *i.e.*, H.T. to the valve anodes and L.T. for valve filament supply, for this set is drawn from separate generators which are coupled to a motor-wound to suit the available electric supply on the submarine. The H.T. generator delivers D.C. H.T. at 2,500 volts, while the L.T. generator delivers 16 volts. The accumulator battery of 14 volts is normally floated across the L.T. generator.

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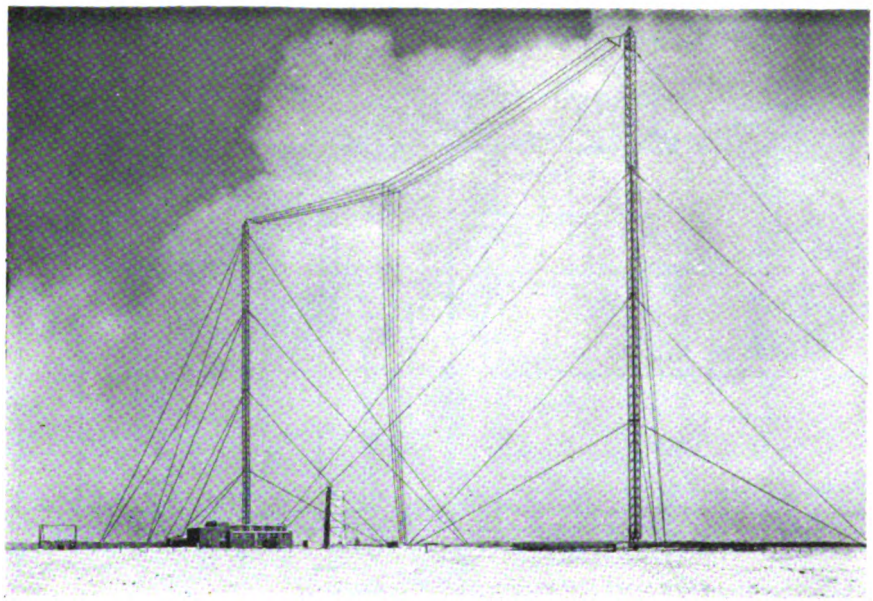
MARCONI NEWS AND NOTES

POLISH BROADCASTING SUCCESS



A general view of the masts and aerials of the Marconi high-power broadcasting station at Rasin near Warsaw.

THE Marconi broadcasting transmitter at Rasin, near Warsaw, which was fully described in THE MARCONI REVIEW, No. 25, has now been put into operation by the Polish Broadcasting Company and has proved an outstanding success both in range and quality of transmission.

The station has been clearly received all over Europe and many other parts of the world. More than 700 reports from British listeners in all parts of England, Scotland, Wales, Ireland and the Channel Islands, provide a sufficient indication of the success of the station from the point of view of the distant listener.

The following brief extracts indicate the tenor of the reports received :—

> " Reception brilliant and without fault. Another advance—a splendid achievement—by the firm which stands for everything that is good in wireless."

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"Strongest and clearest I have had of a foreign station."

"Reception absolutely perfect, as clear as London. Purity most marked; no fading."

"It sounded like the English National Programme until I heard the announcer say it was the Marconi Station near Warsaw."

"Magnificent is the only word that correctly defines the reception. Of all the British and foreign stations we are able to get we have never heard anything so plainly."

"Strength exceptionally good, no fading, quality better than anything heard in ten years experience."

"I have never received a station on high wavelength with such volume. At the same time quality was extremely good with absolute freedom from fading."

That the eastward range of the station is no less remarkable is shown by its inclusion under the heading "Important new broadcasting stations heard in February" in the *Ceylon Radio Times* of March, with the comment that the Warsaw station was "received at wonderful volume and with splendid modulation." To indicate this station's remarkable range it is only necessary to remark that the station is approximately 4,500 miles distant from Colombo, and that it is not working on short waves but on the wavelength of 1,114 metres, with a power of 158 kw. (C.C.I.R.).

The Complete Scheme.

The second high-power Polish broadcasting station, at Lwow, was opened in March, and has also proved highly popular with listeners in Poland and many other countries on account of its strength and clarity.

The station at Lwow is of the Marconi P.A.6 Type, and, as in the case of the Warsaw transmitter, is operated on the principle of low power modulation. The power of the transmitter is 16 kw. of unmodulated carrier energy; it may be modulated up to 80 per cent., and the C.G.I.R. rating is therefore 21 kw.

The station operates on a wavelength of 381 metres.

The third Polish high-power broadcasting station is now under construction at Wilno, and the construction of three local relay stations is to be begun in the near future. This will complete the reorganisation of the Polish broadcasting system.

The outstanding success already attained by the Warsaw and Lwow stations clearly demonstrates that when the final plan is completed Poland will be in possession of a broadcasting service which, from a technical, cultural, and international point of view will be unsurpassed in any country in the world.

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Lighthouse Wireless Telephone.

A FURTHER interesting example of the utility of the Marconi fixed wavelength telephone apparatus is the equipment, with this type of apparatus, of the Smalls Lighthouse, off the coast of Pembroke, South Wales, to the order of Trinity House, to enable the men on duty to keep in touch with the shore.

The wireless telephone in the lighthouse will be as simple to operate as the ordinary domestic telephone, the turning of a switch making the apparatus instantly available for transmission or reception. A call bell is also to be installed, operated by wireless, so that the lighthouse keepers can be summoned to the telephone at any time without the necessity of maintaining a regular wireless watch.

For the shore end of the service, similar equipment, with a wireless call bell, is being installed at St. David's Head, Strumble, South Wales, the nearest convenient point on the British mainland.

Known as the Marconi Type X.M.B.1a equipment, the telephone sets employed comprise a combined transmitter and receiver operating on a fixed wavelength. This is determined in advance and the apparatus is adjusted permanently at the time of its installation. The transmitters are of 100 watts power, the energy being derived from wind-driven generating plant.

First Marconi Station in the United States.

HISTORICAL data often take time to verify and we make this our excuse for having at this later date to amend in certain important particulars the account received from New York which we published on pages 30—32 of our issue of December, 1930, of the early history of the Babylon and Seagate stations.

The first Marconi land station in the United States was erected at Navesink Lighthouse, near Sandy Hook, New York Harbour mouth, in September, 1899, for reporting the America Cup Yacht Races and was a commercial venture paid for by the *New York Herald* although dismantled when the races were finished.

The next Marconi land station in the United States was erected in August, 1901, at Siasconsett, Nantucket Island, to work with a Marconi Station installed on the Nantucket Lightship to report passing ships to the *New York Herald*. This station was worked for many years reporting shipping and handling passengers' Marconigrams. Also at the same time that Siasconsett was being started, two temporary stations were erected by the Marconi Company at Navesink again and at Long Beach and reported the America Cup Yacht Races of 1901 for the *New York Times*.

Later, in July, 1902, another coast station was erected at Sagaponack, Long Island, for communication with ships nearer New York than Nantucket Lightship.

Babylon followed in November, 1902, for communicating with ships still nearer New York.

Finally, at Seagate, a station was erected to make the last communication with ships before docking or first after leaving.

The shack used as the Wireless Station at Babylon, Long Island, therefore, which was referred to in our December issue, dates from 1902.

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THE MARCONI REVIEW

May-June, 1931

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Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

FIELD STRENGTH MEASUREMENTS OF SHORT WAVE TRANSMISSIONS

The following analysis of the results of a series of systematic measurements of Short Wave signal intensities, made at the Research Laboratories of the Marconi Wireless Telegraph Company at Chelmsford, covers the period October, 1930—*January,* 1931.

THE measurements were made with the type 205 signal measuring apparatus described in THE MARCONI REVIEW (May, 1929).

Checks of the performance of the apparatus were also described in the same article, and it is hardly necessary to comment further on this, other than to state that a comparison was made with apparatus used by the Post Office (Designed by Friis of the American Telegraph and Telephone Company Limited), and agreement within about 10 per cent. (on the average) was obtained.

The stations chosen for observation were as far as possible those with well defined C.W. carriers, *i.e.*, telephone stations (working regularly) and multiplex beam stations.

With such stations it is easy to match the heterodyne note of the signal with that of the auxiliary oscillator in the signal apparatus. For completeness the Marconi beam stations, India and Australia, were included, although they have a modulated note and are consequently more difficult to measure. The following is a list of the stations systematically observed.

TABLE I.

STATION.	APPROXIMATE WAVELENGTH.	NATURE OF TRANSMISSION.
Java (Bandoeng)	14·5 metres	Telephone
Buenos Aires	15·2 ,,	,,
Java (Bandoeng)	16 ,,	,,
Cape Town	16·08 ,,	Multiplex Telegraph
Poona	16 ,,	Modulated C.W.
New York	16·4 / 20·7 ,,	Telephone
Melbourne	25·7 ,,	Modulated C.W.

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Station.	Approximate Wavelength.	Nature of Transmission.
Rugby..	27·8 ,, ..	Telephone
Sydney	28·6 ,, ..	,,
Montreal	32·1 ,, ..	Multiplex Telegraph
Bodmin GBK ..	32·3 ,, ..	,, ,,
New York	32·5 ,, ..	Telephone
Cape Town	33·7 ,, ..	Multiplex Telegraph
Bodmin GBJ ..	34 ,, ..	,, ,,
Grimsby	34·2 ,, ..	Modulated C.W.
Poona	34·5 ,, ..	,, ,,
In November the following were added—		
New York	44·41 metres ..	Telephone
Rugby..	43·45 ,, ..	,,
In February—		
Cairo	21·7 metres ..	Modulated C.W.

In general during the winter months, two eight hour watches were kept from 0800 to 2400 G.M.T. for 3 weeks in the month and a night watch for the remaining week.

In taking an observation a record (on a recording millimeter) was usually run for a few minutes and was calibrated by means of the signal measuring apparatus. In giving a numerical value to the strength, the usually rather well determined peak values were used. Mean values could be obtained from the records, but the labour would be excessive and probably hardly justified.

Some of the observations for the months October, November, December, January, are plotted in the accompanying figures, 1—12 inclusive.

It will be observed that the scatter of the points is excessive on the results obtained from Montreal and New York where the routes pass close to the north magnetic pole and the results are subject to great variations on account of magnetic disturbances. It is no rare thing to find a variation of 100 to 1 in signal strength from day to day (at a given time) on these routes.

The scatter of the observations of the South African signals is very much less and may be associated with the fact that this service is relatively free from magnetic effects. (See curves A and B) (Fig. 16).

The excessive variability is confined to the stations New York 16·4 m., Montreal 16·5 m., New York 20·7 m., Montreal 32·1 m., in fact to the America route. For

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such observations it is very difficult to give any significance to the monthly averages which have been plotted in each case. But for the purpose of the analysis of the results some definitive figures must be given and the average, being the simplest representative figure, was taken.

In certain cases the diurnal intensity curve predicted from shadow charts* is included as a check on the accuracy of such predictions. For this purpose the predicted R strengths have been translated into microvolts per meter.

An approximate relation (over a limited range up to R9) between R strength and field strength has been obtained and this relation is exhibited in the curve (Fig. 13).

The charts and this relation have been used to compute the predicted curves. It will be found that there is a fair agreement, thus justifying the method, and by inference the theoretical considerations, on which the charts were based.

During the months considered, the month-to-month variation of the average signal strength was not great except for Montreal and New York. Thus the mean strength on Montreal increased nearly tenfold between October and November, and although the mean value for December was not quite up to the November level, a high level, compared with the October one, has been maintained ever since. The gain in the New York signals between October and November is not so marked, being 4 or 5 to 1, but is still very significant. This change might be a seasonal one, but in the opinion of the author, is probably due to magnetic disturbances. Nine days of magnetic storms were reported in October, one very considerable storm being recorded on October 17th, and only four in November.

The average signal intensity depends probably more on the frequency of minor disturbances than those great enough to be reported as magnetic storms and there is no doubt that October was a very disturbed month in this respect. The fact that only the American routes were largely affected seems to point to magnetic activity as the cause of the low level of such signals.

Variations with Magnetic Cycle.

In comparing the results obtained in these few Winter months in 1930-31, with those obtained qualitatively in the same months of 1927 (R strength observations), the most striking difference is in the behaviour of the 30 m. night transmissions over the transatlantic route.

* A description of these charts and their use was given in a paper entitled "World Wide Communications with Short Wireless Waves," by T. L. Eckersley and K. W. Tremellen, read before the World Engineering Congress, held at Tokio in October, 1929, and in an abstract of this paper published in the MARCONI REVIEW for February 1930.

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Whereas in 1927—1928, signals on this wavelength were generally maintained at a commercial level throughout the night, in 1930—1931 signals dropped to such low values after midnight that they became useless for traffic, and longer waves were found to be necessary. On the other hand there have been indications that the daylight attenuation on wavelengths of the order of 25 to 50 metres decreased on the North Atlantic routes.

It appears possible that gradual changes in short wave transmission have been occuring since 1928.

Perhaps these results may be taken as evidence of a cyclic change associated with the eleven year sunspot or magnetic cycle. The year 1928 was near a sunspot maximum. Although the evidence cannot be considered in the least conclusive, the changes are such as might reasonably be expected if this were the case.

Attenuation.

Although these results cover a very considerable ground, it will be found that if predictions are required for other services, there are always differences in geographical conditions, which make it difficult to apply any one of the results without some degree of interpolation. From a purely practical point of view, some sort of theory to connect up the isolated observations into a continuous body of doctrine is necessary in order to enable one to generalise with some degree of confidence from the limited amount of material available.

Assuming that long distance short wave transmission takes place in the region between the earth and the Heaviside layer, we have to enquire how such factors as the amount and distribution of electronic density in the Heaviside layer, the collision time, etc., affect the transmission characteristics. In a recent paper the writer has shown that whatever the type of layer, the received intensity, at distances large compared with the skip distance, consists of terms of the type

$$\frac{A}{\sqrt{\sin\theta}}\, e^{-\alpha_r d} \sin\left(\frac{2\pi l_r d}{\lambda} - 2\pi v t\right)$$

where α_r the attenuation constant, and l_r the direction cosine of the ray depend on the constants and distribution of electronic density in the upper layer.

d is the distance measured along the earth's circumference from transmitter to receiver and θ the angular separation of the two stations, so that $d = R\theta$, R being the earth's radius. v is the frequency.

The facsimile experiments described by the author in the Proceedings of the Institution of Radio Engineers (Vol. 18, No. 1, January, 1930), enable one to particularise this formula a little more closely, at least for the type of transmission disclosed by these experiments.

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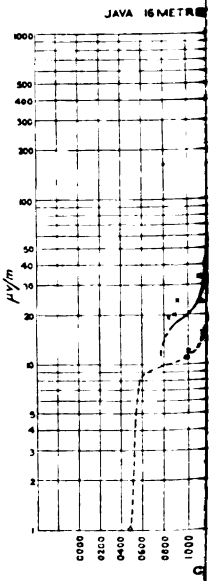

FIG.

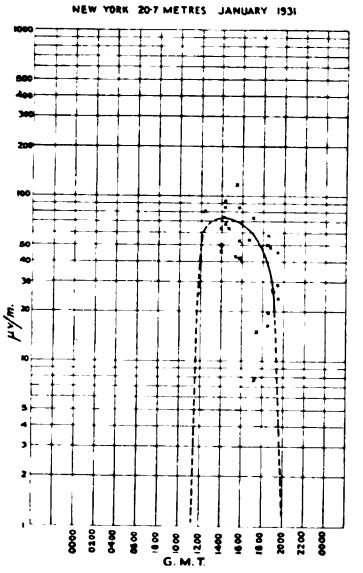

FIG. 6.

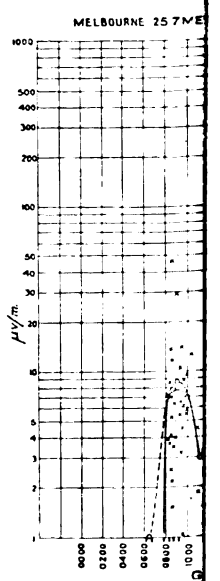

FIG.

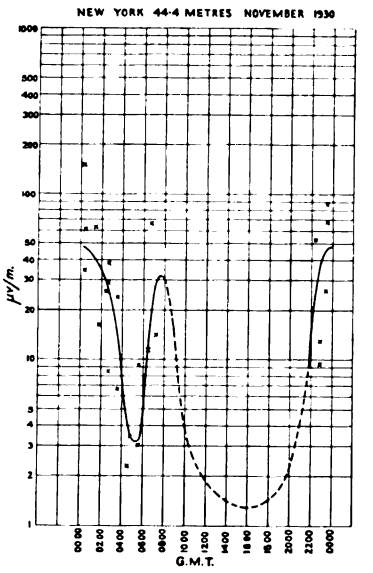

FIG. 12.

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The experiments described indicate that on this wavelength and route, *i.e.*, 22 m. on the New York—Somerton route, the transmission is carried out by the rays usually 4 or 5 in number refracted (fairly sharply) at a height of about 340 km. in a region where the electronic density is about 9×10^5 (see Fig. 14). These rays pass, with very little bending through the lower layer at the height of 90 to 100 km. above the earth's surface (N about 10^5). In this region collisions between electrons and ions are so frequent that considerable attenuation ensues. From the experimental results it appears that the attenuation is much the same for all rays, a conclusion which follows theoretically if we integrate the attenuation along each path.

There is no definite phase relation for the phases of the EMF's of such rays, and we must, according to Rayleigh's law, add up the energies of each ray.

Now the energy of each ray is $\frac{(3\pi)^2 W}{(R \sin \theta)^2} e^{-2\alpha_r d}$

W = power radiated and the total received amplitude is

$$E = \left\{ \sum_{r=1}^{r=n} \frac{(3\pi)^2 W e^{-2\alpha_r d}}{(R \sin \theta)^2} \right\}^{\frac{1}{2}}$$

If α_r is the same for all the rays this is

$$E = \frac{3\pi \sqrt{W n}}{R \sin \theta} e^{-\alpha_r d}$$

Now n can be expressed in terms of the skip distance. In the simple theory outlined above n is approximately the ratio of d the total distance, to d_0 the skip distance

i.e.,
$$E = \frac{\sqrt{R\theta}}{\sqrt{d_0}} \frac{3\pi \sqrt{W}}{R \sin \theta} e^{-\alpha d} \quad .. \quad .. \quad .. \quad (5)$$

In order to conform with the form (1) we write R sin θ for Rθ and obtain

$$E = \frac{3\pi \sqrt{W}}{\sqrt{d_0 R \sin \theta}} e^{-\alpha d} \quad .. \quad .. \quad .. \quad (6)$$

If a beam is employed of magnification M, E will be increased M fold and the final simplified formula is

$$E = \frac{3\pi \sqrt{W_1 M}}{\sqrt{d_0 R \sin \theta}} e^{-\alpha d} \quad .. \quad .. \quad .. \quad (7)$$

For this type of layer, as explained in the facsimile paper, α should be proportional to λ^2.

The observations obtained are compared with the numerical values derived from this formula, in order to see how far actual conditions conform to the rather idealised conditions assumed (see Table II.).

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For this purpose we have to make an estimate of W the power radiated in each case, and M the magnification factor. In general for long distance transmission quite considerable changes in the assumed values of W and M will make but little difference to the final calculated value of α, so that an accurate estimate of them is not required.

The only unknown quantity in the formula is the equivalent attenuation coefficient α, and by comparison with experiment this value can be found.

This is shown in the final column and for convenience the value αd, for 10,000 km., which in round numbers is of the order of 5, is given.

Confining our attention to daylight attenuation in the A and B grades,* and excluding New York and Montreal in October as abnormal, we find that the value of αd does not vary over a large range. The following table shows this.

TABLE II.

STATION.	λ	MONTH.	αd	GRADE.
Buenos Aires	15·2	October	4·38	A–AB
		November	4·19	A–AB
Cape Town	16·08	October	5.45	all A except 1,000 km.
		December	5·07	A–AB
		October	2·37	B
		December	3·30	
New York Phone ..	16·45	November	4·03	B
		December	5·94	B
Poona	16	October,		
		November	5·26	A–AB
		December	5·66	AB–B
Montreal	16·5	November	5·01	B
		December	5·70	B
New York	20·7	November	4·47	B
		December	6·25	B
Montreal	32·1	January	8·7	B

It will be seen that the values only vary between 4·03 and 6·25 (except for Montreal on 32·1 m. and South Africa in the B Grade).

In attempting to find the attenuation law the difficulty lies in the insufficiency of the material. Thus not only is it difficult to find a long distance route (which is required for satisfactory determination of α) all in one grade, but it is next to impossible to find such a route on which there are observations on widely separated wavelengths.

The only cases are those of Montreal and New York on 16, 20·7 and 32·1 metres respectively.

* Grades of shadow density in charts referred to on page 3.

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We can also compare South Africa in B grade (λ16 m.) with Montreal in the same grade on 32·1 (assuming that the B grade in the lower latitudes has the same characteristics as on the Montreal route).

The various values are plotted in Fig. (15) in which the ordinate is αd and the abscissæ the square of the wave length. The results are meagre. Most of them, being in the neighbourhood of λ 16 m., give no information of the wavelength variation of α.

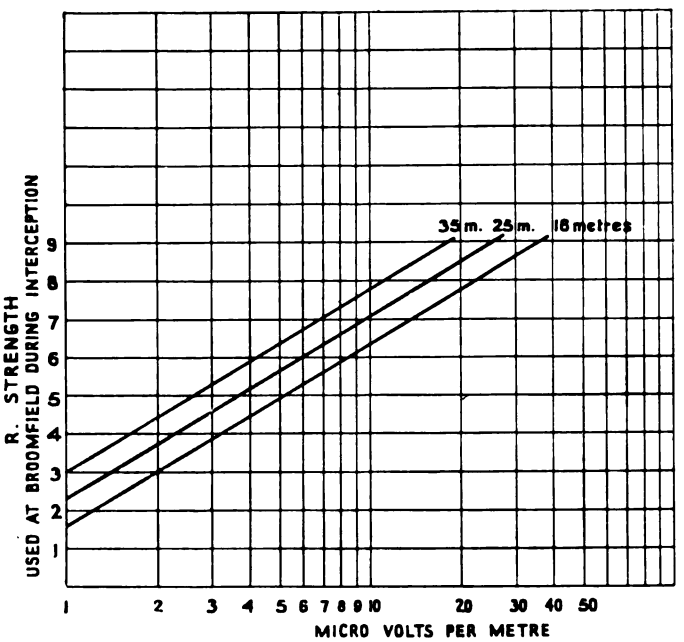

FIG. 13.

One fact is remarkable. The attenuation factor over the New York route of only 5,500 km. (on 16 m.) in B grade is as great as the attenuation factor for the A grade on South Africa, or more than twice the attenuation for the B grade from South Africa.

Fixing our attention on the transatlantic route and comparing the 16 m. and 32 m. stations we see at once that the attenuation coefficient does not vary with λ^2 as it should do. For waves $<$ 25 m. there is some unexplained attenuation over and above that determined by the λ^2 law. If, however, we compare South Africa on 16 m. on the B grade with Montreal on 32 m. on the same grade, we find that α is very nearly proportional to λ^2 in this case. It is probable that the abnormally high attenuation on the Transatlantic routes on the shorter waves, say below 25 m.

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is caused by magnetic storm disturbances and is connected with the abnormal variability of signal intensities at such times.

According to the results on South Africa, the attenuation on the A grade is some 2 to 2·5 times greater than that on the B grade. This agrees with the qualitative difference found on analysis of the years' interception results at Chelmsford where the ratio of the attenuations for the A and B grades is 2 : 1.

Although the evidence cited here is entirely insufficient to establish the λ^2 law (in normal conditions) yet when taken in conjunction with the qualitative attenuation charts* where the analysis of a large amount of qualitative data shows attenuation coefficients for A and B grade as proportional to λ^2, this may be considered as a confirmation (except for the Transatlantic route).

The attenuation coefficient determined by the method described above is an overall figure and depends to a certain extent on the accuracy of the assumed first factor, *i.e.*,

$$\frac{3\pi\sqrt{W\,M}}{(d_0\,R\sin\theta)^{\frac{1}{2}}} \quad .. \quad .. \quad .. \quad .. \quad (8)$$

A more definite figure for the attenuation would be obtained if it were possible to determine the field intensity at all distances.

The only observations of this nature are the field intensity measurements made on the voyages of the *Homeric* (6—12 June and 14—21 June, 1930).

These observations were made under rather disturbed magnetic conditions, and the evariation from day to day and insufficiency of the material make it rather a matter of guess-work to draw the smooth attenuation curve. These observations are discussed more in detail elsewhere. The attenuation constant was determined from the " distance—field intensity " curve in the following manner.

Assuming it to be of the type

$$\frac{A}{\sqrt{R\sin\theta}}\,e^{-\alpha d} \quad .. \quad .. \quad .. \quad .. \quad (9)$$

then $$\log E = \log A - \tfrac{1}{2}\log R\sin\theta - \alpha d \quad .. \quad .. \quad .. \quad (10)$$

or $$\log E + \tfrac{1}{2}\log R\sin\theta = \log A - \alpha d \quad .. \quad .. \quad .. \quad (11)$$

We plot the quantity $\log E + \frac{1}{2}\log R\sin\theta$ against d. The slope of this curve, if E is of the form expressed in (10), should be a constant and equal to α.

Actually we find that the slope is not constant, being greater for small values of d than for great ones, suggesting that the intensity is the sum of a number of components, the more absorbable of which are rapidly attenuated in the initial stages, leaving the less rapidly absorbed components to traverse the greater distances.

* See papers referred to in footnote of page 3.

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The average attenuation slope (between 1,500 km. and 5,000 km.) estimated by two independent workers is $6{\cdot}3 \times 10^{-4}$ and $6{\cdot}0 \times 10^{-4}$ so that the attenuation over 10,000 km. distance is 6·3, or 6·0. These figures are of the same order as those determined for the New York Telephone on 21 m. for the B grade. The *Homeric* tests were taken in summer, when the Transatlantic route is in the A grade. The figures therefore refer to the A grade.

These attenuation constants are rather less than those attributed to the A grade (according to Fig. 15). This is no doubt partly due to the fact that the *Homeric* attenuation was measured as an average for distance 1,500 to 5,000 km., whereas the overall attenuation which includes the shorter distances, is greater as it includes the more absorbed rays weeded out earlier than 1,500 km. in the transmission range.

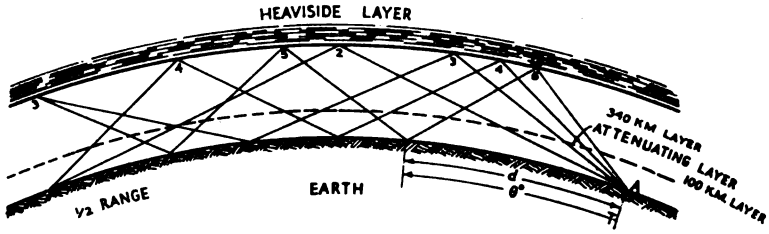

FIG. 14.

The measurements suggest that the overall attenuation measures are not greatly in error, and that consequently the first factor $\frac{3\pi\sqrt{W}}{\sqrt{d_0}\, R \sin\theta}$ is probably approximately correct. They do however, suggest that it is not entirely accurate to consider each ray as equally attenuated (as was assumed in the derivation of formula (6). In practice it would appear probable that the overall attenuation factor would tend to diminish with distance.

In accordance with the assumed mechanism of transmission used in deriving formula (6) it should be possible to calculate the attenuation for each ray, and hence the overall attenuation, if the distribution of ionic density and collision frequency in the lower 100 km. layer is known.

The knowledge of these factors is by no means complete, but there is sufficient data to justify an attempt at the theoretical prediction. This calculation was made for $\lambda = 22$ m., for which wavelength facsimile experiments have given the ray paths.*

We require to know the distribution of ionic density in the layer. This was determined from Appleton's results (published in Proc. Physical Society of London,

* See "Multiple Signals in Short Wave Transmission." Proceedings of the Institution of Radio Engineers. Vol. 18, Jan. 1930, p. 106.

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Vol. 42, Part 4, p. 321), the values being taken during the period two hours after sunrise, which corresponds to a grade between A and B. The collision frequencies were those given by S. Chapman (Proceedings of the Royal Society, Vol. 122, p. 369) and are calculated from the Kinetic Theory for an atmosphere in which wind mixing occurs up to heights of 110 km. and in which the temperature at or in the neighbourhood of 100 km. is assumed to be 300°C.

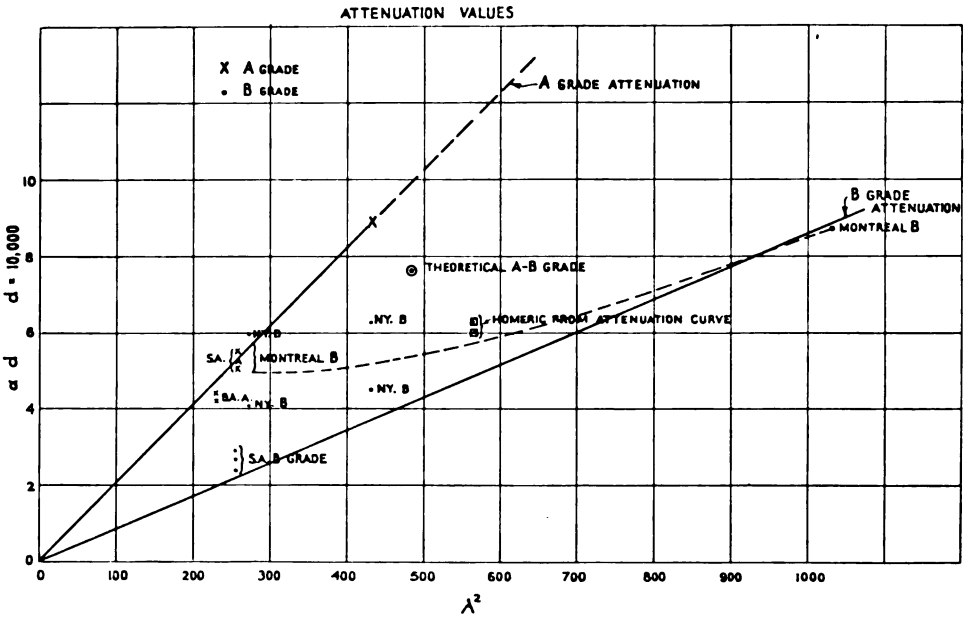

FIG. 15.

The attenuation per centimeter of path where the electron density is N and the collision frequency $\frac{1}{\tau}$ is approximately $\frac{Ne^2}{\pi m \gamma^2} \frac{1}{2c\tau}$. N and $\frac{1}{\tau}$ being known at every point of the path, it is possible to integrate the total attenuation along any path joining receiver and transmitter.

The results obtained are :—

RAY.	θ	$\alpha d_{5,500}$	$\alpha d_{10,000}$
2	10°	3·86	
3	21°	3·86	
4	28°	3·80	
5	36°	5·20	
		Mean 4·18	7·6

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This excludes a calculation for the first ray which cannot penetrate the lower layer. The calculation for this ray depends on a more accurate specification of the density distribution than is obtainable.

The value obtained, 7·6, is between the extremes observed for the 20 m. New York Telephone circuit. It is rather larger than the value, 6·3, obtained from the *Homeric* readings, but reasons for considering this a rather low value for the overall attenuation have already been given. On the whole, considering the nature of the data, the agreement is as near as could be expected.

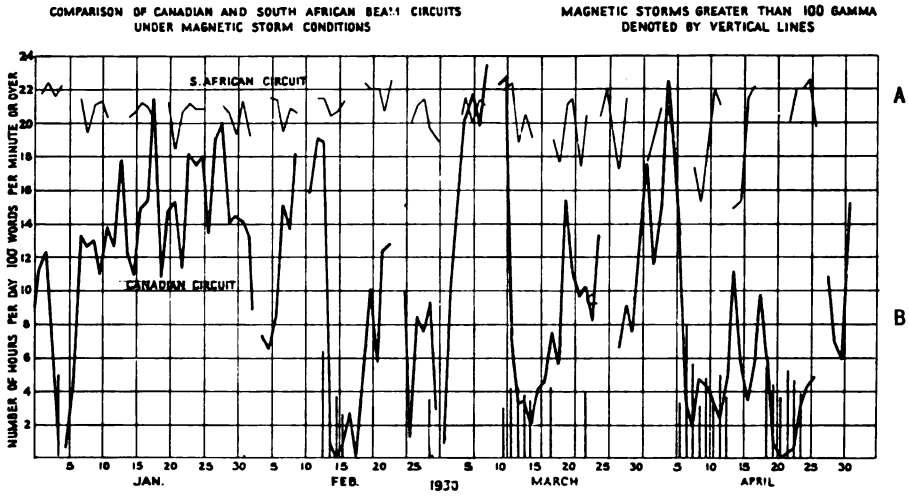

FIG. 16.

Night Transmission.

Whereas day transmission is largely controlled by attenuation, night transmission is chiefly controlled by electron limitation. This factor, which depends on the maximum ionic density in the highest layer, varies throughout the night on account of recombination. It also varies with latitude in such a manner that it is difficult to find long distance paths in which the conditions are uniform. This added difficulty, in the case of night transmission makes a serious complication.

In considering the ideal case of a uniform condition along a route in darkness, a formula of the same type as (1) may be used. The theoretical justification for this is obtained in the fact that the mechanism of transmission is just the same *i.e.*, ricochets between the earth and Heaviside layer, the differences consisting only in the change in density in the upper layer, and according to Appleton's measure-

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ments,—a reduction in density and rise in equivalent height in the lower layer. These both have the effect of reducing the attenuation of any ray passing through the lower layer. In applying a formula of this type to the more general case, a difficulty in estimating the effective skip distance occurs, for the skip distance appropriate to the layer conditions varies along the path. In such cases the skip distance at that end of the route at which it is greatest has been taken. The information gained in the years' interception at Chelmsford (1927—1928) indicates that this is the controlling factor in such a case. Where a region of low electronic density is halfway between a receiver and transmitter, it appears to have less effect than if this region were at either end, suggesting that if the lower angle rays can get a good start (or finish) they can jump a region of lower density as shown in the figure.

With this proviso it is possible to make a comparison between the observed results and those calculated from the formula, assuming there is still residual attenuation. The results obtained are almost wholly for the longer wave stations $\lambda > 25$ m. since, especially in winter time, the short wave stations cannot work through the hours of darkness.

It appears that even at night-time we must assume that there is some residual attenuation. Part of this may be due to an under-estimate of the skip distance, values of which were obtained from experience during the last few years of sunspot maximum. There is evidence, as already cited of a gradual increase of skip distance as sunspot minimum is approached.

The effect of scattering in the late hours of darkness introduces further complications in the analysis of night transmission.

Such scattering signals will not behave in the same way as the main signals, and it is doubtful if we are in a position to make any theoretical estimate of their behaviour.

It will be better to leave this analysis to a later occasion when more material has accumulated.

T. L. Eckersley.

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MARCONI PORTABLE PICTURE APPARATUS

The Marconi Portable Picture Transmitting and Receiving Apparatus has been designed to provide means of a semi-portable nature, to enable rough sketches, maps, weather charts and the like to be transmitted by wireless from the air to ground or between two ground stations.

THE following description of the Picture Transmitting Apparatus deals only with that part of the complete installation which serves to control the modulation of the aircraft or ground wireless transmitter. The details of the design of its output circuits are bound up to a large extent with the methods employed in the wireless transmitter itself for normal operation when transmitting continuous wave telegraphy or telephony, and are omitted.

Each of these normal types of transmission is provided for by readily interchangeable output circuit units in the Picture apparatus which are referred to respectively as the " C.W. Keying Unit " and the " Tone Amplifier Unit." It is the design of these output units which is affected by that of the wireless transmitter which is to be employed.

The standard output units are designed primarily to operate in conjunction with the Marconi Aircraft Transmitters Types AD.18a or AD.19. The standard C.W. keying unit would successfully control a C.W. transmitter which complies with the following :--

1. It should be capable of being keyed at very high speeds.
2. It should be " driven " by a separate master oscillator.
3. It should be capable of keying by the application of a negative bias of from 60 to 90 volts to the grids of the master oscillator and the magnifier valves.

Condition No. 1 above is an essential one for any transmitter with which it is required to utilise the Picture Apparatus. On the other hand deviation from No. 2 and No. 3 may probably be accommodated by suitably adapting the design of the C.W. keying unit or the addition of an intermediate linking unit between the two instruments.

When the telephony range of the transmitter is sufficient for the service required the method of transmitting the pictures by modulation of the carrier wave may be employed by means of utilising the Tone Amplifier Unit in lieu of the C.W. keying unit.

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With this type of transmission the technical requirements in the output circuit are less exacting and the standard output unit will be found suitable to operate with most telephone transmitters of moderate power with, in some cases, the addition of an output transformer between the Picture Apparatus and the modulation circuits of the transmitter, or an additional stage of L.F. magnification.

Conversely, the function of the Picture Receiving Apparatus is essentially to utilise the output from a wireless receiver which is tuned for the reception of signals

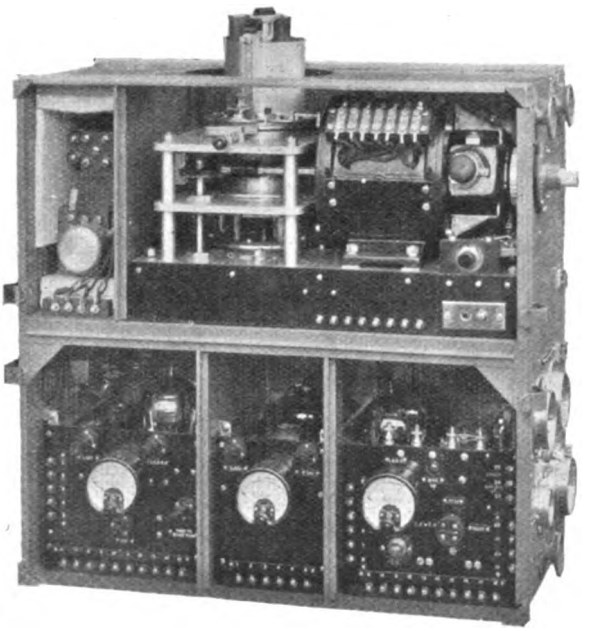

FIG. 1.

from the transmitter discussed above, in order to record the signals in visible form in such a manner as to reproduce the sketch which is being transmitted.

It may be successfully operated by any good-class, selective receiver which is capable of giving 8 to 10 milli-watts of undistorted power at the output terminals.

The performance of the Picture Receiving Apparatus is naturally dependent upon that of the wireless receiver with which it is operated.

Transmission.

The sketch or plan to be transmitted is made upon a specially prepared form

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consisting of very thin metallic foil mounted upon a stout paper backing. The surface of the foil is covered with a non-conductive fine tissue, the three layers of the form being made perfectly homogenous. A fountain pen containing a special solution of graphite is used for sketching which impregnates the tissue and renders it electrically conductive where marked by the pen. An alternative type of form the surface of which is capable of being rendered conductive by marking with an

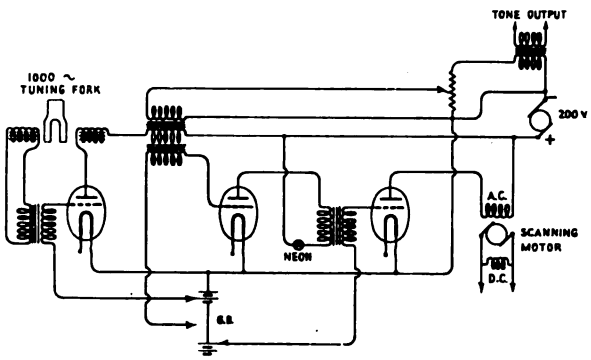

FIG. 2.

ordinary lead pencil may also be supplied. The sketch is placed around a cylindrical drum, tissue outwards. Along one edge the foil is left exposed and is thereby connected in the electrical circuits of the apparatus.

The whole surface of the form is now explored by a metal stylus point which revolves continuously around the cylinder, while the latter maintains a steady end-wise movement of 1/80th part of an inch per revolution of the stylus.

The parts of the tissue which have been impregnated with graphite permit of the passage of current between the stylus and the foil as the former passes over them. The blank portions of the tissue are however entirely non-conductive and the circuit is opened when the stylus rests on these portions.

This successive closing and opening of the circuit is utilised through suitable stages of amplification to control the output of the picture transmitter, which (in the case of the standard C.W. keying unit) consists of a difference in potential of 80 volts produced across a resistance when the stylus is on " mark," this negative potential being applied to the transmitter valve grids for keying.

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For telephony modulation of a transmitter using the standard tone amplifier unit, the output consists of a 1,000 cycle note when the stylus is on " mark," which is applied to the modulating circuits of the wireless transmitter.

Constancy of speed of the motor driving the scanning mechanism is maintained by tuning fork control, by a method to be described later.

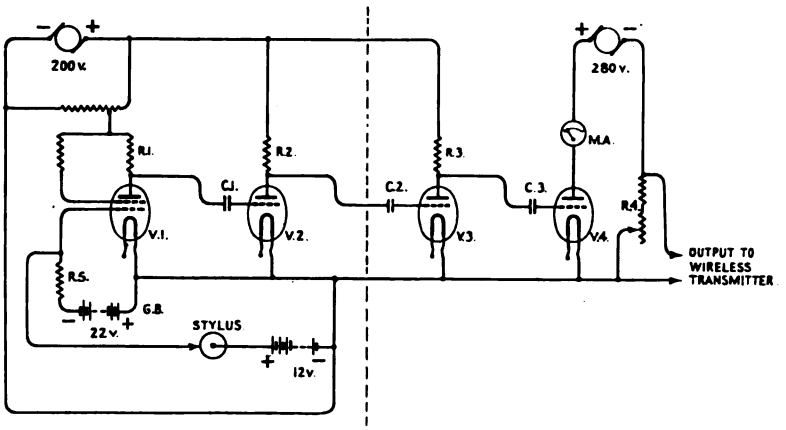

FIG. 3.

Reception.

The mechanical features of the scanning mechanism and drum in the Picture Receiving Apparatus are duplicates of those in the transmitter. Speed control in this case, however, is obtained by utilising the output from a 1,000 cycle inductance-capacity circuit in lieu of the tuning fork control. The tuning of this circuit is variable, by means of an adjustable condenser, over a small range which enables the frequency of the transmitter fork to be precisely duplicated, and perfect synchronism between the transmitter and receiver drums to be maintained.

The medium employed for recording the received signals consists of an absorbent paper form moistened with a solution of potassium ferri-cyanide and common salt.

This form is scanned by the iron stylus of the receiver in synchronism with the movement of the transmitter stylus over the surface of the message.

The output from the wireless receiver is taken through a transformer to the grid of a valve which is backed off to the rectifying point, in the anode of which are connected the stylus and drum. The train of signals is thereby recorded upon the

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message form by the local coloration of the solution, produced by the passage of current through the paper during "marking" periods.

Owing to the synchronism existing between the movements of the transmitter and receiver scanning mechanisms the resultant record is a reproduction of the sketch or message transmitted, having a scanning mesh of 80 lines to the inch.

An example of a message transmitted from air to ground over 80 miles is shown in Fig. 6.

Design.

The main requirements for the service in view which have formed the basis

FIG. 4.

of the design of the apparatus may be summarised as follows:

The transmitting apparatus must be compact and as light as possible, suitably encased for housing in aircraft when required.

The operator should be able to make a rough sketch or write a message and transmit it straight away without delay or preparation.

The useful area of the message form should be at least 8½ inches by 4½ inches.

The time taken to scan this area completely should not be greater than 5 minutes.

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At the receiving end it should be possible to observe the picture continuously as it is being received therefore the cylinder on which it is recorded must not revolve and the record should be immediately visible without further processes to be carried out.

Synchronism between transmitter and receiver must be maintained by means which are independent of any transmitted signal, since if this is not so, any jamming by interfering signals would cause not only the loss of a portion of the picture but also of synchronism. To avoid this would require a very high signal interference ratio and consequently a very limited range would be possible.

As many parts of the transmitting and receiving apparatus as possible, such as recording drums, scanning mechanism, motors, etc., should be interchangeable.

Provision should be made to enable the receiving stylus to be correctly phased with that of the transmitter in relation to the edges of the message forms, in addition to maintenance of their synchronised speeds.

It should be possible to remove and replace the cylinders without stopping the scanning mechanism with consequent loss of phasing and synchronism.

The above conditions have all been met in the design of the apparatus under consideration.

Details of Transmitter.

The Picture Transmitter Type P.T.1a is illustrated in Fig. 1.

The Scanning Stylus Mechanism will be seen in the top compartment, on the left of which is the tuning fork control.

The scanning mechanism consists of a stylus mounted on an annular ring revolving in a horizontal plane about the central cylinder round which the picture is clipped. The cylinder, which is 3 inches in diameter, does not revolve but is supported by three guide rods and has a steady vertical movement of 1/80th part of an inch per revolution of the stylus, which is imparted by means of a lead screw driven through a worm reduction gearing.

The stylus makes 90 revolutions per minute, the scanning speed being fourteen inches per second. The time of transmission is therefore 4½ minutes for the maximum area of 9·4 inches by 5 inches. In practice a small percentage of this area at the margin is lost in operating.

The motive power is supplied by a small machine of the motor alternator type running at 1,666 r.p.m. which drives the stylus and lead screw through reduction gearing.

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The D.C. side of this machine is supplied from a 12 volt accumulator or other source of power and takes approximately 36 watts. The A.C. side is in the anode circuit of the last valve of an amplifier, the input to which is controlled by the 1,000 cycle tuning fork. The constant frequency output of this valve is thus applied to the A.C. windings of the motor serve to keep its speed perfectly uniform.

A stroboscopic wheel on the shaft of the motor is illuminated by a Neon lamp which is connected in the anode circuit of the first valve of the fork amplifier and provides a positive indication that the motor speed is under the control of the fork impulses.

A small cam mechanism is mounted on the stylus ring and is operated by push rod from the front of the apparatus. This cam is used to raise the stylus off the cylinder at the end of a message, and allows the cylinder to be removed, and a duplicate cylinder ready charged with the next message to be inserted without loss of time, while the stylus ring is still revolving.

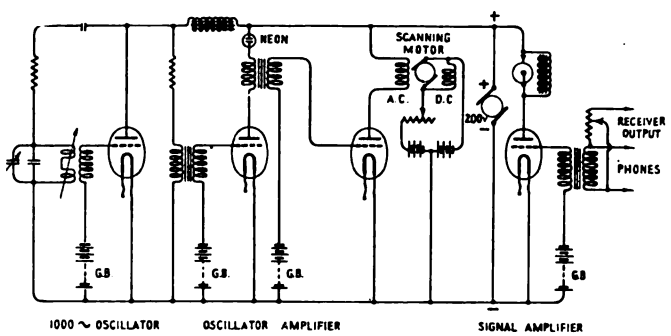

FIG. 5.

The stylus itself is supplied in the form of a ribbon whose width is equal to the mesh of the picture. This ribbon is fed out of its housing as required thereby compensating for the wear which takes place more especially at the receiver, due to the electro chemical action.

The cylinder engages with the lead screw by means of a half nut which is raised or lowered into mesh with the screw-threads by means of a knob operated from the top of the cylinder. The latter can be rotated by hand in order to obtain the correct phase relationships between the transmitter and receiver.

The Tuning Fork Amplifier is contained in the left hand bottom unit shown in Fig. 1. It comprises three valves, the first of which maintains the fork in vibration in the usual manner. The consequent 1,000 cycle oscillations are then amplified

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by the succeeding valves, which are transformer coupled ; this frequency is then passed via the anode of the last valve through the A.C. windings of the scanning motor to control its speed. For telephony working this tone is also applied by means of a transformer to the tone amplifier unit.

Fig. 2 shows the theoretical diagram of this unit and the scanning motor.

The centre section of the bottom half of the case is occupied by the intermediate amplifier unit, comprising a screened grid valve which is capacity coupled to a second amplifying stage. The control grid of the first valve is maintained at a negative potential when the stylus is on white by a grid bias battery through a high resistance R_5 (Fig. 3). This grid is also connected to the positive side of the common 12 volt battery through the drum and stylus, which when on white holds off this positive potential. There is therefore no voltage drop across R_1 when the stylus is on white and the grid of the limiter valve V_2 becomes less negative thus allowing current to pass in this valve with a consequent drop across R_2.

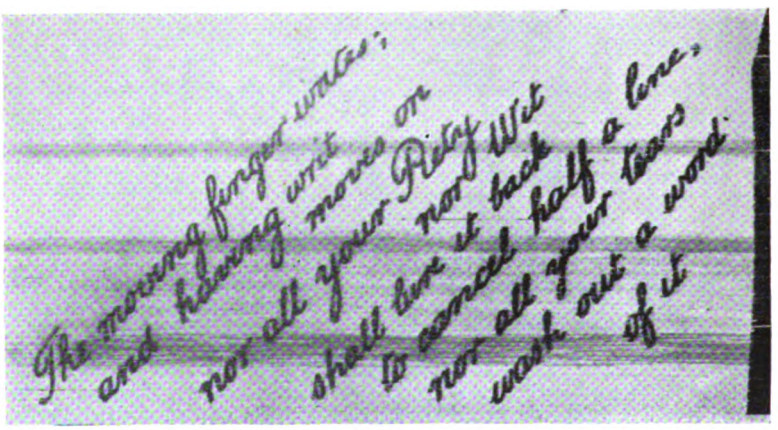

FIG. 6.

The voltage applied to C_2 is then of such a value as will allow the accumulated negative charge on the grid of V_3 to back this valve off. C_3 receives a positive charge and V_4 is conductive. The drop across R_4 is thus available for application to the transmitter grids for keying.

When the stylus is on mark a small current flows through R_5 and the grid of V_1 becomes positive. Hence the drop in R_1 causes V_2 to be backed off. This renders V_3 conductive and V_4 is backed off. No drop then occurs across R_4 and the transmitter grids are relieved of the negative potential, allowing the transmitter to oscillate.

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Output Unit.

This is housed in the right hand bottom compartment and may be either the C.W. keying unit, the operation of which is described above, or the tone amplifier unit if telephony modulation of the transmitter is employed.

A three way switch is incorporated in the C.W. keying unit which enables the wireless transmitter to be used either independently of, or in conjunction with, the picture transmitter. The third position of the switch enables the picture transmitter to be tested out when the wireless transmitter is shut down.

Receiver Type P.R.1a.

The general construction of the receiving apparatus is similar to that of the transmitter. It is illustrated in Fig. 4. The top half is occupied by the scanning mechanism with a grid bias battery compartment on the left.

In the bottom centre is the 1,000 cycle oscillation generator unit, with its amplifier on the left. The amplified oscillations are employed to control the speed of the scanning motor in the same manner as the tuning fork output in the transmitter unit described above. On the bottom right hand is the signal amplifier which amplifies the output from the wireless receiver.

The anode of this amplifier valve is supplied with H.T. current at 200 volts through the stylus and receiving drum. The passage of feed current to this valve through the receiving form when the valve is rendered conductive by the swing of grid voltage caused by the incoming signal, is recorded by the production of the familiar Prussian Blue colour on the form.

The theoretical diagram of connections of the receiving apparatus is shown in Fig. 5.

Synchronism

It has already been stated that synchronism is accomplished by means of a tuning fork at the transmitter and a 1,000 cycles oscillator at the receiver. In order to check the synchronism it is only necessary to observe the message drawn at the receiver during the reception of a picture, and watch the formation of the reproduction of the bar which clips the message on to the cylinder at the transmitter. If the received bar deviates slightly in either direction from the vertical it indicates that the receiver stylus is running either too fast or too slow as the case may be. By slightly adjusting the frequency of the 1,000 cycles oscillator this can be corrected at once, in practice very little attention to synchronism being necessary.

Power Supplies.

When used in aircraft the Picture Transmitter receives its high tension power supply from a wind driven generator fitted with a constant speed windmill. The

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generator is of the double output type and provides current at 280 volts to the anode of the last valve of the C.W. keying unit when this is employed, and at 200 volts to the anodes of the remaining valves. This generator is independent of that which supplies the wireless transmitter.

The valve filaments are heated from one half of the 12 volt accumulator which drives the scanning motor, and changeover switching is provided whereby either half of the accumulator may be employed at will for the filaments to maintain an even discharge of the cells.

When used on the ground the double output generator may be driven by a motor or the H.T. current may be supplied from suitable batteries or other local source.

When telephony modulation is employed the 200 volt supply is alone required.

The receiving apparatus requires a H.T. supply of 200 volts and this may be derived from the rotary transformer provided which is driven from the 12 volt accumulator used for the scanning motor and filaments, or may be obtained from a H.T. accumulator or other suitable local source.

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TELEPHONE TRANSMITTING EQUIPMENT ON BOARD THE "HOMERIC"

The following description applies to that type of short wave telephone transmitter which was originally designed for use on Marchese Marconi's yacht, the " Elettra," *operating on one spot wavelength of 26 m. A number of important demonstrations which were given with this set, were described in* THE MARCONI REVIEW *for April, May and August,* 1930.

Transmitters of similar design, but modified to make them suitable for the short waves of 9.87 m. and 9.77 m. respectively, are now being employed on the Rome-Sardinia commercial duplex telephone service.

The White Star Liner " Homeric " *has a transmitter of the* " Elettra " *type, but in this case an additional panel is employed to provide alternative wavelengths of 24 m. and 70 m.*

Another of these transmitters has been erected recently on the " Empress of Britain," *and it is hoped to describe the installation on this ship in the next issue of* THE MARCONI REVIEW.

THE Radio Telephone installation on board the " Homeric " has been designed to enable a regular telephone service to be established from that ship to Great Britain and the United States of America, which has since been extended to include several other countries.

At the shore end in Great Britain, transmission takes place from the Post Office Rugby Station, while the Post Office Baldock Station is employed for reception from the ship. These stations are connected to the London Trunk Exchange, thus enabling a normal telephone service to the ship to be provided from anywhere in Great Britain.

On board the " Homeric " a special extension of the Marconi wireless cabin has been built to house the transmitter and receiver, and a telephone room has been erected nearby from which passengers can make their calls.

The complete installation includes the transmitter, receiver and terminal equipment.

The Transmitter.

The transmitter consists of four separate units :—

(1) The rectifier unit.
(2) The modulator unit.
(3) The short wave oscillator unit.
(4) The long wave oscillator unit.

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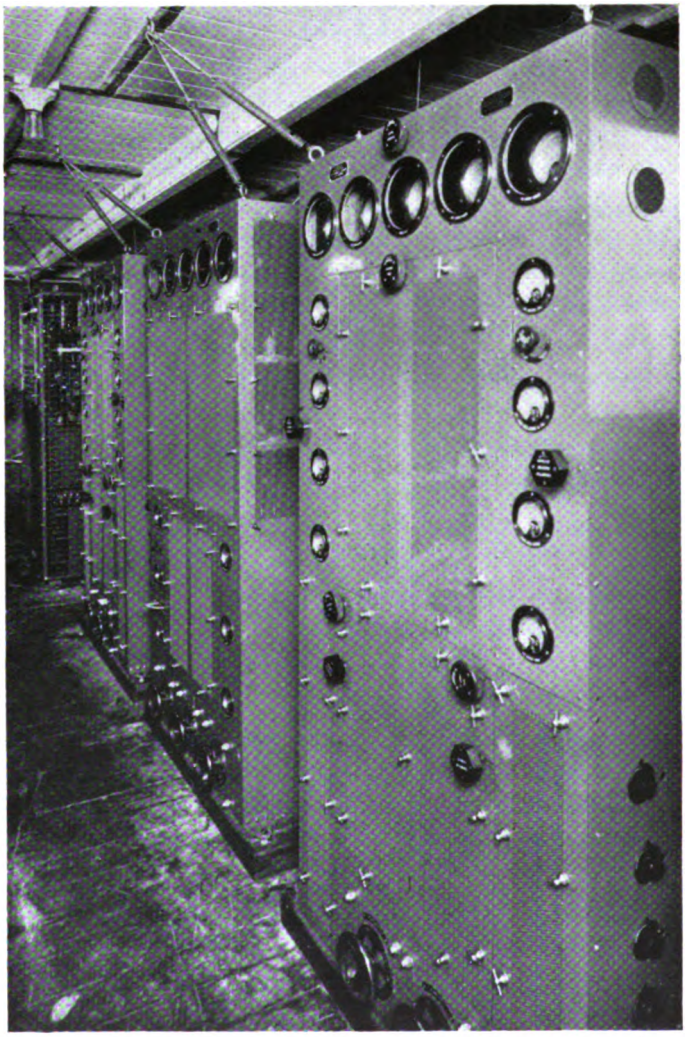

Transmitter Panels on board the "Homeric."

Power Supply.

The rectifier unit for power supply to the valves consists of suitable valve rectifiers and their associated circuits, for converting the high tension alternating current into direct current.

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Single phase alternating current from the generator is transformed to the required voltage in the main power transformer and is thence rectified by two M.R.9 valves. The smoothing system has been carefully designed to obtain a very steady rectified current to ensure high quality speech transmission.

The main filament supply to the valves is from a direct current generator. The master oscillator filament supply is from a battery, and grid bias and master oscillator anode supplies are from small rectifier units.

The main power transformer is mounted as a separate component.

Modulator Unit.

This unit consists essentially of one sub-sub-modulator valve, type M.T.4b, the grid circuit of which is modulated via a transformer by the speech currents. The sub-sub-modulator is resistance capacity coupled to a sub-modulator valve type M.T.6b, and this is resistance capacity coupled to four main modulating valves type M.T.9L.

The anodes of the main modulators are connected to the high tension supply through a speech choke, which varies the high tension supply to the anode of the third power amplifier in accordance with the magnified speech variations.

Oscillator Units.

Two separate oscillator units are provided, one for the short wave of approximately 23 metres, and one for the long wave of approximately 70 metres.

The power stages of these oscillators are controlled by their respective master oscillator. These master oscillators consist of specially designed valve circuits, comprising a valve oscillator and frequency doubling stages. The valve oscillator is so designed that, once set to any frequency, any change of filament voltage, anode supply voltage, or temperature that is likely to occur in practice up to 1 per cent. will not affect the frequency to more than one part in 25,000.

The frequency of the master oscillator can be adjusted to within about 4 per cent. either side of the medium wave, which in the case of the short wave oscillator is approximately 2,136 k.c. (141 m.). This fundamental frequency is doubled at the first screened grid valve stage of the amplifying section of the master oscillator unit. The output is then amplified before the frequency is tripled in the third stage. The frequency output of 12,820 k.c. (23·4 m.) is then passed through two more stages of amplification before being input to the power stages. In the long wave master oscillator the initial frequency of 2,150 k.c. (139·5 m.) is amplified in two stages and is doubled at the third stage. The output is then further amplified in the fourth and fifth stages.

Constant frequency of the oscillator with change of temperature is obtained by means of an inductance and condenser assembly which when once adjusted

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automatically compensates for any expansions or contractions due to varying temperature.

The master oscillator units are shown in the bottom right-hand compartment of the second and fourth panels from the left in the photograph.

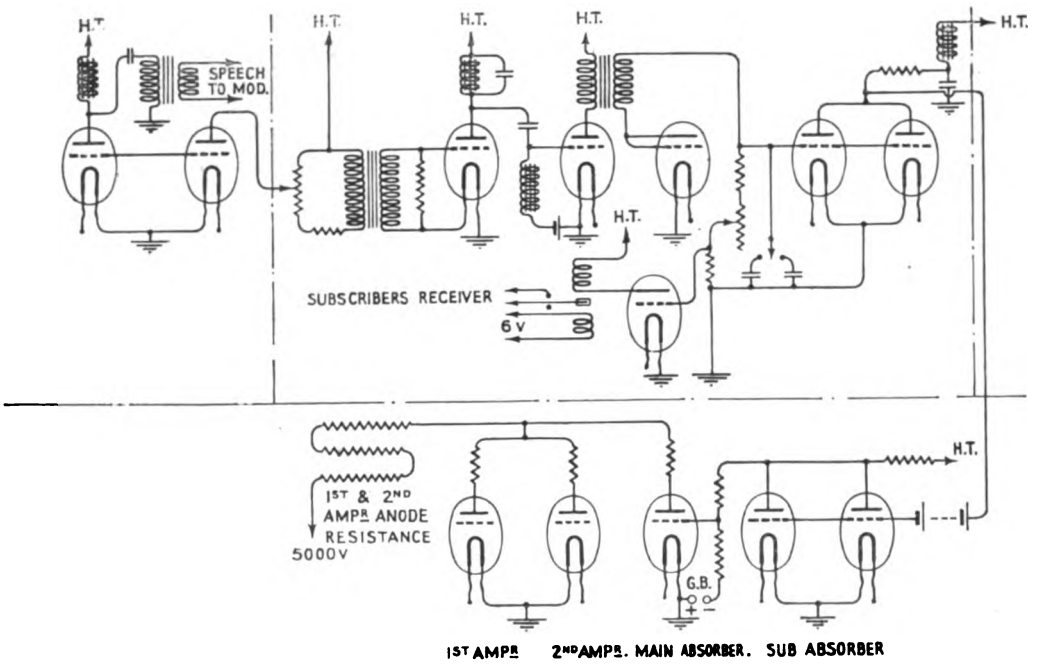

FIG. 1.

Power Stages.

The output from the final stage of the master oscillator unit is capacity coupled to an auto transformer for feeding the grid circuit of the first amplifier.

The power amplifier consists of three stages of amplification. The first and second amplifiers are single valve stages and are neutralised by connection in the form of a bridge, the capacities of the valves being balanced by means of small variable condensers in the opposite arms of the bridges.

Semi-fixed coupling is used between all the power stages in the following manner. A comparatively high inductance is connected across the output circuit of the preceding stage, and the grid circuit of the next stage which is part of the bridge network is connected through fixed condensers across a suitable amount of this inductance.

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The grid circuit is roughly tuned by a second inductance.

The third stage of amplification consists of two valves in opposite arms of a bridge network but is otherwise similar to the preceding stages.

The output circuit consists of a coupling coil and series condenser, with a series coil which is connected either in place of or in series with the tuning condenser as required by the aerial conditions. The output circuit on this ship is connected to the aerial direct.

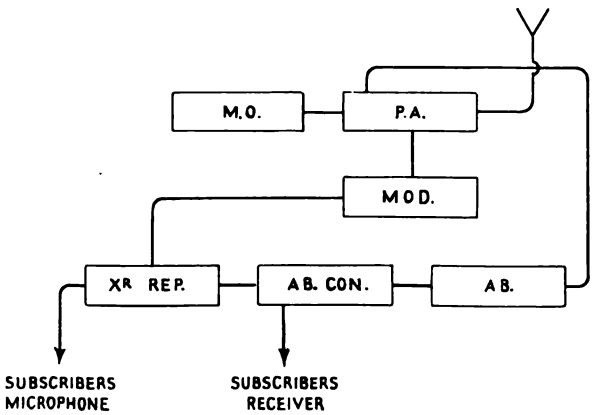

FIG. 2.

The Absorber System.

The absorber circuits are provided in order to cut off the carrier during the periods when no modulation is applied to the transmitter, and thus assist in obtaining quiet reception.

From the diagram of connections shown in Fig. 1, it will be seen that the speech currents from the microphone act on the grid circuits of two valves in the transmitter repeater, one of these valves serves to transfer the speech variations to the modulator system of the transmitter, the other operates the absorber control unit which in turn actuates the absorber system.

The absorber control unit consists of two stages of audio frequency amplification, a diode rectifier, two valves in parallel (the sub-sub-absorber valves) operating as a further amplifier stage, and an additional valve which serves, by relay action, to open the subscriber's receiver circuit when the transmitter is being modulated by him.

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The action of the absorber control unit is as follows. Audio frequency applied to the input of the unit produces a unidirectional current in the anode circuit of the diode rectifier and alters the potential of the grid circuit of the sub-sub-absorber valves which are connected to earth through a resistance capacity network having a definite time constant. This time constant is so adjusted that once the carrier has been started by the absorber system acting on the anode voltage supply of the power amplifier, it can be retained for the required fraction of time after the modulation has ceased.

The relay valve which disconnects the subscriber's receiver circuit, is operated off a part of the potential applied to the sub-sub-absorber valve grids. Due to the presence of this relay the cutting off of the carrier must not lag too long behind the cessation of modulation, as otherwise the reception of speech may be "clipped" and interjections, etc., lost.

The absorber system itself comprises two stages, a sub-absorber, and a main absorber, arranged as a D.C. amplifier. The main absorber draws its anode current through the common anode resistance of the first and second power amplifiers. Thus when the main absorber valve is taking its correct anode current, the voltage supplied to the first and second power amplifiers is reduced to such a low figure that the third amplifier delivers no power to the aerial.

A switch is provided on the control circuit to put the absorber entirely out of action, and provision is made to read the anode current of all valves and the grid current of the sub-absorber in the receiving room. The absorber can also be controlled by means of a switch in the transmitter room.

A schematic diagram of the components of the transmitter is given in Fig. 2.

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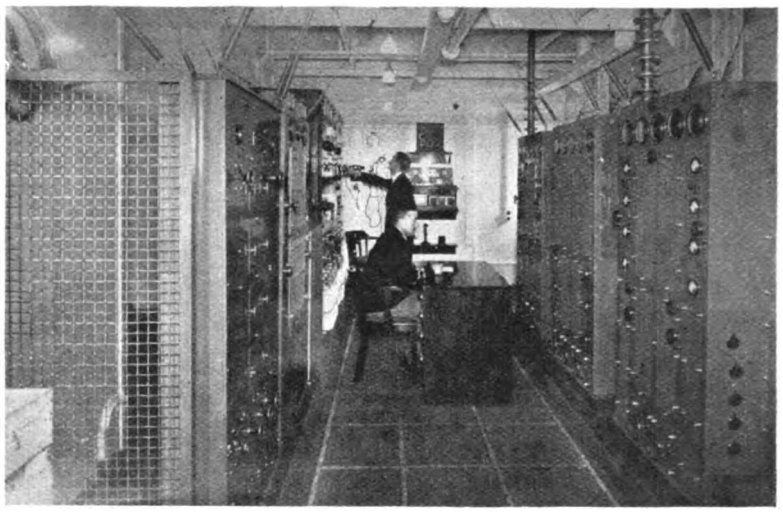
MARCONI NEWS AND NOTES

"EMPRESS OF BRITAIN": MARCONI WIRELESS TELEPHONE



Marconi telephone transmitter room on board the "Empress of Britain."

WHEREVER the luxurious new Canadian Pacific liner, the "Empress of Britain" may be in the Atlantic during one of her summer runs between Southampton and Quebec or in the Pacific Ocean or in the China Sea on one of her winter round-the-world cruises, her passengers will be in telephonic communication with the world's land telephone network, for she carries the largest and most powerful Marconi wireless telephone equipment of any ship afloat. It is also the first wireless telephone installation to be planned before the ship was built thus giving the wireless and telephone engineers an opportunity of planning and building it in the most efficient manner.

Its possibilities were demonstrated to the public on both sides of the Atlantic during the maiden voyage by broadcasts arranged from the ship. When about 500 miles out from Southampton a conversation between Captain Latta, her Commander, and Commander King-Hall at the British Broadcasting Corporation's Headquarters in London was broadcast and heard with the greatest clearness throughout Great Britain. On approaching Canada a similar broadcast was arranged for the benefit of listeners in Canada and the United States. This included a speech from the ship by Mr. E. W. Beatty, President of the Canadian Pacific Railway, and an orchestral concert.

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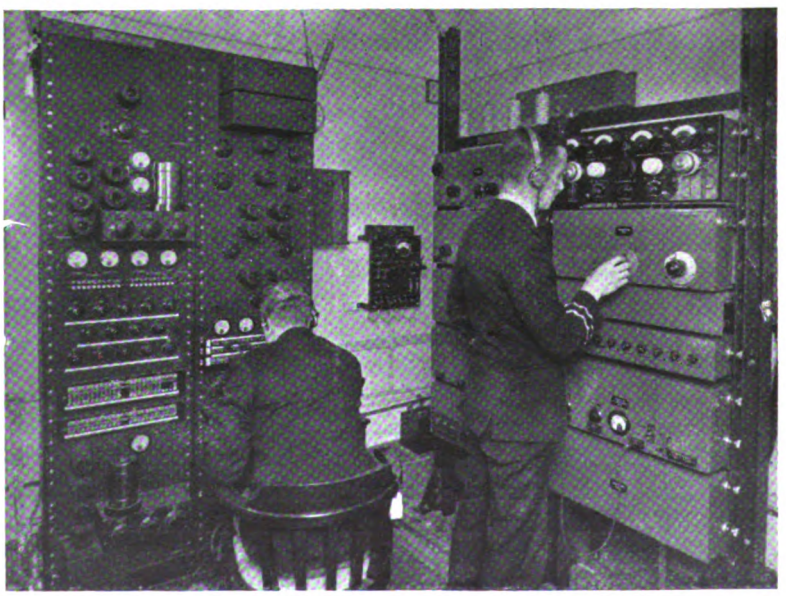
Three large rooms are devoted entirely to the wireless equipment which, in addition to the wireless telephone, includes long and short wave telegraph transmitters and receivers, a Marconi Wireless Direction Finder, and emergency and lifeboat equipment.

The short-wave telephone equipment is similar to that used by Marchese Marconi in his series of experiments in world-wide telephony from his yacht "Elettra" in the Mediterranean early last year, but incorporating many new features which have been developed since that time.

A special feature of the "Empress of Britain's" equipment is the ability to speak from any of the ship's telephones, which are connected to the wireless apparatus through the ship's manual switchboard, so that the telephone service on the ship is as convenient as that on shore.

The enterprise of the Canadian Pacific Company in providing long-distance telephony as part of the normal wireless service of the "Empress of Britain" is an indication that, as the telephone has become an integral part of modern life for business, social and domestic affairs on shore, its extension by wireless to shipping will eventually become as general as the linking of countries and continents.



Marconi telephone receiver room on board the "Empress of Britain." *On the left is the monitoring equipment and switchboard, and on the right the receiving apparatus.*

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Prince of Wales's Flight.

THE reliance placed upon wireless in air travel was indicated by the journey made by the Prince of Wales from Bordeaux to London in bad weather on April 27th and 29th. At the request of Imperial Airways Limited, Mr. T. A. Vallette, the Marconi wireless operator and engineer who accompanied the late Lieut.-Commander Glen Kidston on the first stages of his record trip to South Africa, was placed in charge of the Marconi wireless installation on the "City of Glasgow," in which the Prince of Wales flew from Bordeaux to London. The installation was of the world-famous Marconi A.D.6 type, arranged for operation either by the pilot in the cockpit or by the operator, the latter being enabled to employ either telephony or telegraphy as required. As is well known, the Marconi A.D.6 "All-purpose" aircraft equipment comprises a highly efficient transmitter of 150 watts power and a special receiver of extreme selectivity and stability.

For the guidance of shipping: a Marconi Automatic Wireless Beacon station in course of erection at Mizzen Head, Ireland.

The first stage of the journey with the Prince of Wales and Prince George and their party was from Bordeaux to Le Bourget, Paris, on April 27th. Communication with the ground was easily maintained throughout the flight in spite of bad weather, the Prince of Wales and members of his party utilising the wireless for private messages, in addition to the normal exchange of weather and position messages and information regarding the organisation of the flight.

Bad weather conditions again prevailed on the flight from Le Bourget to Windsor Great Park on April 29th, but the "City of Glasgow" was in touch by wireless with Croydon ten minutes after leaving Le Bourget, with excellent two-way communication. Over the French coast fog was encountered and Croydon was asked for and gave several direction finder bearings, the pilot, Captain G. P. Olley, making use of the wireless telephone for this purpose. The Prince of Wales, who spent most of the time during the flight in the cockpit, was particularly interested in this demonstration of the utility of wireless and in the ability of the pilot to communicate with the ground throughout the flight.

On landing in Windsor Park, Captain Olley demonstrated to the Princes that even when the aircraft was on the ground he could communicate with Croydon to

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report their safe landing. This was done by using the fixed aerial and running the front engine to provide sufficient slip-stream to revolve the generator windmill.

With the Princes in South America.

Marconi aircraft apparatus also rendered very useful service during the visit of the Prince of Wales and Prince George to Chili, both the areoplane and seaplane used for transporting the Prince of Wales during his flights in that country being fitted with Marconi A.D.6 installations. During the flight of the Princes from Antofagasta the machine was in constant touch with the chain of Chilian aerodrome ground stations, and for the whole of the flight from Ovalle to Santiago, a distance of 220 miles, positions were taken every five minutes by the two wireless direction finding stations at Quintero and Santiago, the progress of the machine and aircraft thus being followed and broadcast to an immense crowd awaiting their arrival at El Bosque aerodrome.

The First Marconi Stations in Canada.

THE reference in our last issue to the first Marconi stations to be opened for traffic in the United States has brought forth the following interesting comments from Commander C. P. Edwards, Director of Radio, Department of Marine, Canada.

"I was interested in the historical data given in your recent number of THE MARCONI REVIEW with regard to the first Marconi stations in the United States, and I find on looking up the dates, that Canada was not very far behind, the Marconi stations at Chateau Bay and Belle Isle on the Canadian Labrador, having been established on the 28th September, 1901.

"I have forgotten who was in charge of the work, but I am sure you will be interested to read the following extract from the report of the late D. H. Keeley, Superintendent of Telegraphs, of the Department of Public Works, in regard to this communication :—

> "'The spot selected at Chateau Bay is a quarter mile from the village ; and a special hut for the winter accommodation of the apparatus as at Belle Isle had to be erected.
>
> "'This Chateau Bay installation was in readiness on Sunday the 20th October, when signals from Chateau Bay were received at Belle Isle ; but none were receivable at Chateau Bay. The trouble on investigation was attributed to defective coherers, and the Company's agents proposed abandoning the plant till next year in the absence of a fresh supply.
>
> "'On the 22nd, however, I personally succeeded in establishing communication and was thereby enabled to avert the threatened postponement of operations ; and on the 25th, after considerable practice and careful directions, for all that the working of the system as it stands is erratic, I felt confident in leaving our operators in charge, with the explicit intruction as to future action conveyed in the copy attached hereto.'

"These stations have long passed into oblivion. The Belle Isle station was replaced in 1905 by a standard coast station, and that, in turn, was replaced two or three years ago by a modern station equipped with C.W. transmitter, direction finding apparatus, etc.

"The Chateau Bay station was closed down and the service taken over by a new station at Point Amour about 1904, and that station, in turn, is now about to be replaced by a modern plant."

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July-August, 1931

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THE MARCONI REVIEW

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General Editor: W. G. RICHARDS.

1929-1930 DEVELOPMENTS IN THE STUDY OF RADIO WAVE PROPAGATION

It is essential that the progress made in the study of wave propagation problems applied to radio communication should be summarised from time to time, for the guidance and use of the radio engineer.

In the following article the modern conception of the Heaviside layer, the effect of magnetic storms on wave propagation, the use of ultra short waves and the question of beam transmission are briefly discussed, and the progress made during 1929-1930 *in the solution of the problems associated with these questions given.*

APART from special technical developments involving the improvement of aerials, terminal transmitting and receiving apparatus, valves, etc., in fact the projection and reception of radio waves, a steady progress has been made in our knowledge of the processes of transmission upon which in the end the advancement of the art must depend. It is difficult to point to any outstanding advance in this knowledge, but experimental evidence and theoretical interpretation of this is gradually clearing away the fog of uncertainty in which the processes of transmission are wrapped, and the general nature of short wave transmission is now fairly clearly understood.

The prime factor in interpreting the vagaries of transmission is the Heaviside layer and the contributions to the investigation of this form an outstanding feature of the radio literature published during the last twelve months.

For the purpose of wireless analysis, the distribution of electron density, mean free path, recombination factors and ionisation processes are the most significant.

In Appleton's hands the interference methods of measuring the group time delay of signals reflected from the Heaviside layer, has resulted in a consolidation of our knowledge of the regions where the 80 to 400 m. waves are bent down to the earth.

In particular the evidence for existence of two reflecting and refracting layers has become practically overwhelming.

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Transmissions on 100 m. are very striking in this respect, for the lower layer at an effective height from 100 to 120 km. is not always sufficiently dense (*i.e.*, $N < 10^5$ at times), to return the normal incidence rays and from time to time the rays escape through this layer to a higher one at 212 km. or so, the effect of which is made visible in much more rapidly changing interference fringes indicating a sudden discontinuous change of effective delay and corresponding effective height.

From these results we can picture the layer as increasing in electronic density from 80 km. to a little over 100 km., where $N = 10^5$ approximately, after which N falls away and then increases again to the same value or even higher value at a height of 212 km.

The distribution of density at greater heights requires shorter waves, and facsimile and pulse experiments are yielding further results which in time may be sufficient to give a picture of the electron distribution in such regions.

In connection with electron distribution in the layer an important theoretical advance is in the application by de Groot and Appleton of an integral equation due to Abel to the case of radio transmission. By the use of this a series of simultaneous observations which give the effective echo time delay as a function of the frequency can be made to yield the electron density distribution in the layer.

There is some doubt whether this method, which is based on geometrical ray optics,—admittedly an approximation—is admissible on the lower frequency ranges where the wavelength is comparable with the height of the Heaviside layer. The application of the method is also open to criticism where the ray passes through the lower to the upper layer.

In America the pulse method of investigation of the height of the Heaviside layer, has been advanced by some important investigations. Experiments by Hafstad and Tuve at short distances indicate an echo pattern which changes throughout the day and which may be interpreted as implying multiple reflection between the earth and Heaviside layer although the authors prefer to await further observations before making any definite interpretation. A result of some importance but of which the meaning is obscure, is that the later echoes are generally split into two or more. In confirmation of these results facsimile transmission between Chelmsford and Somerton on 60 m. and 120 m. waves undoubtedly show the existence of multiple echoes of which the simplest interpretation is that they represent repeated reflections between the earth and Heaviside layer at a height of about 210 to 250 km. On this interpretation as many as four complete reflections occur in passing over the relatively short distance of 227 km.

The results of these experiments made early in 1930 are interesting as they give almost identical figures for the effective height (which varies during the evening

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in the same way) as those given by Kenrick and Jen for observations made at the same season a year before in America. Some of these pictures are also of interest as showing an undoubted record of the scattering which was investigated by direction finding methods by the author in the past few years.

This scattering is exhibited as a smudging of the facsimile picture, signals lasting in some cases for a period of some 20 milliseconds after the initial signal.

This is in general agreement with the delay times estimated from directional measurements made by the author.

The analysis of long distance facsimile results has given important information in regard to the nature of long distance transmission.

It has long been in doubt as to whether the signal proceeds from transmitter to the receiver in one long jump through the Heaviside layer or by multiple reflections between the earth and Heaviside layer.

The evidence indicates, at any rate in the cases examined, *i.e.*, New York, Somerton on 22 m., New York, San Francisco on 16-23 m., between Buenos Aires and Nauen on about 15 m., that the normal method is by multiple reflections between earth and Heaviside layer. There is in general a multiplicity of rays, the higher ones constituting longer paths, and the signals following these are delayed, with the result that a single impulse transmitted is generally reproduced at the receiver in multiple form.

Over Transatlantic distances, 3, 4, 5 or even 6 echoes are reproduced, spaced about a millisecond apart. An analysis of the time delays indicates that on 22 m. in the Transatlantic transmission there are in general four or five rays bent down from the Heaviside layer at an effective height of 340 km.

The maximum ray angle is about 35°. From this maximum angle the maximum density in the Heaviside layer may be deduced with fair accuracy. A value of 9×10^5 is obtained. Corresponding to this the minimum wave for long distance transmission is 8·7 m. Waves shorter than this escape through the layer. Although normal transmission proceeds in this manner there are indications that round the world echoes may proceed in a single jump for it is stated by O. Bohm* that, whereas the direct signal from Buenos Aires to Berlin showed multiple—the indirect echo showed none. Records of echo signals are always cleaner cut and of less duration, than the direct signal.

This reflection at 340 km. (in agreement with some results of Kenrick and Jen) may indicate a third layer at this height or a continuous increase in density from about 3×10^5 at 210 km. to 9×10^5 at 340 km. The evidence is not sufficient to decide yet.

* O. Bohm, Mehrfache und Doppler Effekt bei der austreilung wellen Telefunken Zeitschrift, Dec. 1929, Vol. 10, No. 53.

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The results of all these measurements give a fairly clear though not accurately detailed picture of the Heaviside layer.

A study of short wave transmission on broad lines as the result of a whole year's continuous interception of all the regular short wave stations has been published by T. L. Eckersley and K. Tremellen, and the interpretation of the results is based on the conception of the Heaviside layer outlined above.

Charts have been prepared by means of which relative performances of all short wave stations at any time of day or year, wave length, etc., can be predicted with a fair degree of certainty.

The basic idea on which the charts have been prepared is that in the daylight regions for long distance transmission (outside the skip) attenuation proportional to the square of the wavelength is the main factor, and that, secondly, at night time, electron limitation is the main factor.

For daylight transmission there is no doubt that the attenuation proportional to the square of the wavelength is approximately correct (*i.e.*, in agreement with the observations), and the model of the layer outlined above gives a theoretical reason for this, for it is the 100 km. layer which is the attenuating region and the upper layer 210 to 340 which is the bending region. Where attenuation and bending occur in different regions the λ^2 law of attenuation results (see Eckersley-Appleton). The results based on the known mechanism have suggested the following transmission formula :—

$$E = \frac{3\pi\sqrt{W}}{\sqrt{d_0 d}} e^{-\alpha d\lambda^2}$$

W = power radiated (watts).
d = distance.
d_0 = skip distance.
λ = wavelength.
α = attenuation constant depending on latitude and time of day or night.

Results of signal intensity measurements generally give values less than calculated by the above formula but in a more or less constant ratio.

In connection with the electron limitation which occurs at night the facsimile results New York to Somerton on 22 m. afford a means of determining the recombination coefficient of the electrons and ions in the Heaviside layer at night. The method has been described in a letter to *Nature*, and depends essentially on measuring the maximum echo delay which is a measure of the maximum density in the layer. This decreases during the night on account of recombination. This recombination

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accounts for the difference between early and late night transmission which is a feature of the long distance transmission results as well as of the observations of Appleton (Interference Methods), Breit, Tuve, Hafstad, Kenrick, Jen, etc. (Pulse Measurements in America.)

Measurements of this kind are valuable because the theoretical development of the behaviour of the Heaviside layer is hampered by insufficient physical knowledge of ionisation and recombination processes. Such physical measurements cannot be performed in the laboratory and quantum physics is not sufficiently far advanced to give theoretical values to the recombination and absorption coefficients.

Magnetic Storms.

The effect of magnetic storms in radio transmission has been the subject of further study. I. J. Wymore gives the results of the study on *long waves*. By studying statistically the results of field intensity measurements (E), he finds that there is a definite but slight increase of E following the height of a magnetic storm. It may require as many as 6 or 7 days for E to revert to normal.

Unpublished results on Beam Stations, Canada, South Africa and India, using traffic returns, show very marked correlation between magnetic storms and hours of traffic worked at 100 w.p.m. and over, especially during the year 1930, for during the first half of this year magnetic storms were very numerous. During and after such storms the hours worked at high speed are much reduced on the Canadian circuit, but very little reduced on South Africa and Indian circuit. The Australian circuit is most effected on the long path. The results show a correlation in magnetic storm effect with the magnetic latitude. Routes in high magnetic latitude are much more affected than those in low.

Interest has been revived in whistler atmospheric disturbances.

Further correlation between whistler storms and magnetic storms have been found. A connection between whistler storms and the earth current variations usually associated with magnetic storms has also been discovered. Such results help to form a mental picture of the mechanism of magnetic storms which together with theoretical researches of S. Chapman and R. Gunn should lead to a complete theory. This knowledge should be of value for radio telegraphic purposes.

K. Tremellen has found that Isolated Whistlers are definitely caused at certain times by local lightning flashes. Schelleng and Barkhausen have suggested an alternative theory of these and suggest that they are caused by multiple reflections between earth and the Heaviside layer. E. T. Burton observed similar disturbance on a submarine cable and has suggested a correlation with magnetic storms.

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The long echoes observed by Jorgan Hals, Stormer, and Van der Pol have not yet received a satisfactory explanation. P. O. Pederson discusses the matter at length in a paper to the I.R.E., and concludes that the only possibility is that the echoes must travel out in space over a distance comparable with that traversed by light in the echo time, *i.e.*, 3 to 30 seconds. This conclusion is by no means accepted. The alternative, *i.e.*, that the echoes travel with very low group velocity in the Heaviside layer has been discussed by Appleton, Van der Pol and C. Breit, who show that serious difficulties attend this explanation connected with the enormous attenuation such transmissions must suffer unless they take place in a very rarified region of the Heaviside layer. In this connection the maximum density in the upper layer as determined by the facsimile results is of significance. Waves longer than 34 m. at normal times cannot escape into outer space. Echo results are obtained on shorter waves than this so the first explanation is possible.

On the other hand it is just possible that on occasions the regions at greatest height in the layer are just sufficient to hold down the rays, in which case long delay in the uppermost regions of the layer will occur. This region being where the attenuation is least it is possible that long delay echoes occur on the rare occasions on which the layer is sufficiently dense to refract such waves.

Further interesting data of the occurrence of long delay echoes has been published in "Comptes Rendus," by Galle and Talon, and summarised by Stormer in Proc. Roy. Soc., Edinburgh, Vol. 4, Part 2, No. 15.

Galle and Talon observed long echoes in Indo-China on 8th, 9th and 10th May, 1929, on a wavelength of 25 m. Many observations are given varying in delay between 2 and 30 seconds.

In connection with the escape of wireless waves into outer space through the Heaviside layer, Eckersley has discussed the question from the physical point of view, showing that the earth's magnetic field modifies the physical processes of transmission and that a wave suitably circularly polarised and oriented with respect to the direction of the earth's field can escape through the Heaviside layer in regions where, in the absence of such a magnetic field, the electronic density is sufficiently great to prevent escape. This paper gives a physical reason for the results predicted by the ordinary magneto ionic ray theory.

These results have an application to the long delay whistler echoes observed by Tremellen and Eckersley.

Ultra Short Waves.

These have been studied by Franklin, Mathieu and others in England, and the successful ultra short wave communication link between Rome and Sardinia has resulted.

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Esau and Hahnemann in Germany have published results and Jagi and Uda in Japan. In America the Radio Corporation have made use of 3 m. waves in linking up by telephony the Hawaian Islands. Experimental evidence shows that transmission on waves below about 8 m. is practically confined to the direct ray, *i.e.*, there is no evidence (except possibly on rare occasions) of any energy being reflected from the Heaviside layer on these waves. This is in accordance with the results obtained by the facsimile echo methods where it was shown that normally the short wave long distance limit lies between 8 and 9 m. Esau and Hahnemann show that the range of such short waves is practically confined to the optical range. These results are confirmed by experiments of H. Fassbender and G. Kurlbaum, made from an aeroplane on 3 m. When the receiver passes within the shadow of the earth's hump, signals are very rapidly reduced. Similar results were found in Honolulu where the transmitter had to be placed at such a height on a mountain that the straight line from transmitter to receiver was tangent to the earth's surface at the latter. From time to time reports of long distance ultra short wave transmissions beyond the optical range have been made, but they seem to be the exception rather than the rule.

Beam Transmission.

The gain of a Beam array over a single element of the array has been the subject of several studies both from the theoretical and practical point of view.

The behaviour locally is already well known and calculations have been made for a great variety of arrays by Southworth in which the fundamental element of the array is assumed to be a doublet and the effect of earth conductivity is neglected.

Over long distances the estimated gains are not always attained in practice (Schelleng Technical Publications of Bell Telephone Laboratories), and the loss due to incoherence in the ray, *i.e.*, irregular phase changes in the E.M.F. in the wave front is the subject of a calculation by Schelleng (also unpublished calculations by the author, which agree).

Signals fade differently at different points along the wave front, and the distance at which the fading at two points is in a purely random relation is found by Friis to be about 10λ.

It is then shown that the actual gain as compared with the theoretical gain drops off rapidly if apertures comparable or large compared with this distance of random fading, are used.

With regard to the theoretical calculation of the gain of an array over a single element of the array this is a very complicated function of that aperture if the aerial height is small, but tends to a very simple limit if a high uniform aerial is used as the element.

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It can then be shown that in this case where the radiation is confined to a small vertical sheaf of rays the theoretical gain approaches the limit $2\pi x$ aperture where the aperture is the ratio of the width of the array to the wavelength.

A useful summary of the progress in the study of Radio Wave propagation phenomena is given by G. W. Kenrick and G. W. Pickard. (Proc. I.R.E., Vol. 18, No. 4, April, 1930.)

The recent developments are given in Section B and E of this paper and a very complete bibliography is appended.

T. L. ECKERSLEY.

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THE ENERGY MAGNIFICATION OF BROADSIDE AERIAL ARRAYS USED FOR RECEPTION

The energy magnification of aerial arrays used for transmission was first worked out by C. S. Franklin, and an elementary sketch of the method used was given by the author in EXPERIMENTAL WIRELESS, *October*, 1927. *Taking a small aerial in free space as standard, Franklin calculated the energy magnification of a half-wave aerial as* 1·095, *while that of a broadside aerial of the Marconi-Franklin type with reflector was* 9·6 *per square wavelength of the aerial. It was rightly assumed that equal gains would be obtained on reception, but it is nevertheless of interest to examine the question from the receiving point of view.*

---

(1). The Power Received by Single Aerial.

THE power received by a single aerial can be calculated by a method given by Zenneck. It is assumed that it is possible to obtain an aerial with other resistances small compared with its radiation resistance, that the earth is a perfect conductor and that the aerial is parallel to the electric force in the wave front. The effective E.M.F. on an aerial is calculated as follows:—

Let E = Maximum value of field strength in volts per cm. in the incoming wave.
I_x = Maximum value of current in the element dx of the aerial.
I_X = Maximum value of I_x at any point in the aerial.
θ = Phase angle between I_x (at all points in aerial) and E.
h = Length of aerial in cm.
λ = Wavelength in cm.

Then the energy received from the wave

$$= \int_0^h \tfrac{1}{2} I_x E \cos\theta \, dx = \tfrac{1}{2} E_0 \cos\theta \int_0^h I_x \, dx = \tfrac{1}{2} E \cos\theta \, I_X \alpha h$$

where cos θ can be made unity by tuning and $\frac{1}{2}$ is factor due to E and I_x being maximum values, and

α = Same form factor that appears in the formulæ for radiation resistance.

For a small earthed aerial

$$R_{Rad} = 1580 \left(\frac{h\alpha}{\lambda}\right)^2$$

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For a small dipole in free space

$$R_{Rad} = 790\left(\frac{h\alpha}{\lambda}\right)^2$$

αh = effective height (or length)

Hence the effective E.M.F. max. = $E\alpha h$
= E× (Effective height).

Let R_R = radiation resistance of aerial,
R_D = effective resistance of detector in aerial,
both these resistances being referred to the maximum current in the aerial.

Current in aerial = I_X (max) = $\dfrac{E\alpha h}{R_R + R_D}$

Power to detector = $\frac{1}{2}R_D I_X^2$ = $\frac{1}{2}\dfrac{E^2(\alpha h)^2 R_D}{(R_D+R_R)^2}$

This is a maximum for $R_D = R_R$ when its value is $\dfrac{E^2(\alpha h)^2}{8R_R}$

Various cases arise

(A) Small aerial in free space for which

$$R_R = 790\left(\frac{\alpha h}{\lambda}\right)^2$$

Maximum power to detector = $\dfrac{E^2\lambda^2}{8 \times 790} = \dfrac{E^2\lambda^2}{6320}$ watts.

(B) Small aerial at the earth's surface for which

$$R_R = 1580\left(\frac{\alpha h}{\lambda}\right)^2$$

Maximum power to detector = $\dfrac{E^2\lambda^2}{12640}$ watts.

Thus in both these cases under the conditions assumed the maximum power to the detector is independent of the size of the aerial, a rather surprising result. It is the neglect of dead resistance, such as earth resistance, which is usually much greater than the radiation resistance that leads to this result.

(C) Half-wave aerial in free space or near the earth for which a correction factor must be applied to the formula $R_R = 790\left(\frac{\alpha h}{\lambda}\right)^2$. This correction factor is due to the length of the aerial producing a concentration of field in the plane perpendicular to the aerial.

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From formula 790 $\left(\frac{h\alpha}{\lambda}\right)^2$ $\quad R_R = 80$ ohms.

Accurate calculations give

Half-wave aerial in free space	$R_R = 73{\cdot}2$ ohms.
,, ,, with lower end at earth's surface	$R_R = 104$ ohms.
lower end $\frac{1}{4}\lambda$ above earth	$R_R = 69$ ohms.

If the formula 790 $\left(\frac{h\alpha}{\lambda}\right)^2$ were correct the maximum power to detector would be as given in (A) that is $\frac{E^2\lambda^2}{6320}$.

Actual maximum power to detector $= \frac{E^2\lambda^2}{6320} \times \frac{80}{R_R}$

Thus a half-wave aerial in free space will deliver $\frac{80}{73{\cdot}2} = 1{\cdot}095$ times as much power to the detector as a small aerial in free space, *i.e.*, the energy magnification of the half-wave aerial relative to the small aerial is 1·095. This is exactly the figure found for transmission as might be expected since the same calculation is involved.

Let us compare these values with the wave energy going through an area of 1 sq. wavelength parallel to the wave front.

Amplitude of field in E S units $= \frac{E}{300}$ per cm.

Electric energy in unit volume 1 *cc* with this field strength $= \frac{1}{8\pi}\frac{E^2}{300^2}$ ergs.

In one second per sq. cm. of wave front electric energy flowing through $= \frac{1}{16\pi}\frac{E^2}{300^2} \times 3 \times 10^{10}$

The factor $\frac{1}{2}$ gives average value of $(\sin)^2$.

There is an equal amount of magnetic energy

Hence power through 1 sq. wavelength $= \frac{1}{8\pi}\frac{E^2\lambda^2 \times 10^6}{3 \times 10^7}$ watts

$= \frac{E^2\lambda^2}{754}$ watts

We can therefore express the power delivered to the detector as a percentage of the total power flowing through one square wavelength parallel to the wave front.

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(A) Small aerial in free space $\frac{754}{6320} \times 100$ = 11·93%

(B) Small aerial at earth = 5·96%

(C) Half-wave aerial in free space 11·93 × 1·095 = 13%

Half-wave aerial lower end at earth = 9·2%

,, ,, ,, ,, $\frac{1}{4}\lambda$ above earth = 13·6%

If the resistance of the earth is taken into account it will alter the value of the radiation resistance of aerials near earth, and so affect the amount of power that can be delivered to the detector.

(2). Power Received by Broadside Array without Reflector.

Consider an aerial array of the Marconi-Franklin type without a reflector, of dimensions large compared with the wavelength so that edge effects are negligible. In the first place let us suppose the array is correctly tuned, but is not coupled up to a receiving system, so that it has no damping other than that due to radiation. An electric magnetic wave of field strength E striking the aerial system squarely will be practically totally reflected, giving rise to a wave of field strength E travelling in the reverse direction, whilst there will be practically no field behind the aerial system.

Assume that in this case the current in one of the aerials is I_0. If the aerial system is coupled up to a receiver the current induced in the aerials would be reduced to kI_0 where k is a fraction depending on the degree of damping introduced. The field strength of the wave reflected from the aerial will be kE and that of the wave that passes through the aerial will be $(1 - k)$ E.

The power in the incident wave is proportional to E^2, while the power in the reflected and transmitted waves are proportional to k^2E^2 and $(1 - k)^2E^2$.

Hence the fraction of incident power absorbed will be :—

$$\frac{E^2 - k^2E^2 - (1 - k)^2 E^2}{E^2} = 2k - 2k^2 = 2k(1-k).$$

This fraction is a maximum when $k = (1 - k)$, *i.e.*, $k = \frac{1}{2}$ when its value is $\frac{1}{2}$. That is to say the aerial system without reflector can absorb 50 per cent. of the power in that part of the incident wave which strikes the aerial system.

(3). Power Received by Broadside Array with Reflector.

Now suppose a reflector system is placed at a suitable distance ($\frac{1}{4}\lambda$ or $\frac{3}{4}\lambda$ etc.) behind the aerial system, the receiver damping being adjusted so that the current in it is still $\frac{1}{2} I_0$. The wave, strength $\frac{1}{2}$ E which is transmitted through the aerial system will induce a current $\frac{1}{2} I_0$ in the reflector system and there will be no field behind the reflector system. Also the phases of the aerial currents in the aerial

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and reflector system are such that they produce no radiation in the direction opposite to the incident radiation, but produce a wave of strength -- E travelling in the same direction as the incident radiation, so cancelling out the incident wave behind the aerial system. Hence all the energy in the incident wave is absorbed by the receiver. The aerial with reflector when properly adjusted behaves as an ideal black body.

Comparison of the figure for the broadside aerial array with reflector, with those for the single aerials gives the following table :—

Broadside aerial array with reflector compared with	Energy Magnification per square wavelength
Small aerial near earth	$\frac{100}{5{\cdot}96} = 16{\cdot}8$
,, ,, in free space	$\frac{100}{11{\cdot}93} = 8{\cdot}4$
Half-wave aerial in free space	$\frac{100}{13} = 7{\cdot}7$
,, ,, lower end at earth ..	$\frac{100}{9{\cdot}2} = 10{\cdot}9$
,, ,, ,, ,, $\frac{1}{4}\lambda$ above earth	$\frac{100}{13{\cdot}6} = 7{\cdot}4$

These figures though lower than the corresponding figures for transmission, may be correct for aerial arrays of very large extent in both dimensions. The transmission figures are worked out for arrays of moderate dimensions. Such arrays in reception will absorb energy from an area of wave front appreciably greater than the actual area of the array so that the energy magnification figures will be correspondingly increased. Thus an aerial system 2λ high might absorb the energy from $2\frac{1}{4}\lambda$ height of wave front. This would increase the effective area of the aerial by 12 per cent. and would bring transmission and reception figures into agreement.

In all these calculations the earth has been treated as a perfect conductor, a condition it is far from fulfilling. The effect of its resistance will be to decrease the energy received by a single aerial relative to that received by the beam array. If figures for the radiation resistance of an aerial taking earth losses into account could be obtained, it would be possible to calculate the percentage power absorbed by the aerial as shown in the first part of the article.

Although the foregoing calculation shows the energy magnification of a beam array in reception, it should be noted that the chief value of such an array for reception lies in its directivity which increases the signal to noise ratio.

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Another point that arises is whether the radiation resistance of the aerial system when used for reception is the same as when used for transmission. First take the case of a single aerial array without a reflector. In reception a current I_0 produces a plane wave of strength E in one direction only. On transmission a current I_0 produces two plane waves of the same field strength E travelling in opposite directions. For a given current the aerial therefore radiates double the energy on transmission to what it does on reception. That is, the value of radiation resistance for reception appears to be half of that for transmission. The aerial array with reflector, when properly adjusted for reception radiates no energy at all, so that its radiation resistance is effectively zero. From the transmission point of view, the reflector will double the radiation resistance of the array.

The receiver loading on the aerial, however, will be correct when the aerial has been adjusted as a transmitting aerial, *i.e.*, when the aerial load as a transmitter is equal to the surge impedance of the feeder, the actual receiver load being also adjusted to this value. This follows from the fact that for the aerial without reflector the energy re-radiated from the aerial for a current of $\frac{1}{2}I_0$ is $\frac{1}{4}$ of the total energy in the incident wave, or $\frac{1}{2}$ the energy absorbed in the receiver. Hence the receiver load must be double the radiation resistance of the aerial from the reception point of view and equal to the radiation resistance of the aerial when transmitting. The effect of the reflector is to double the absorption of energy by the receiver for a given current. Therefore the receiver load must be doubled. It will then be equal to the radiation resistance of the aerial and reflector when transmitting.

Since the beam aerial with reflector when properly adjusted can absorb all the incident energy it would appear to be inadvisable to use reaction directly on the feeder of such a system.

My thanks are due to Mr. C. E. Rickard, O.B.E., for reading through the manuscript and correcting an error in the formulæ for radiation resistance.

E. GREEN.

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RELAY BROADCAST TRANSMITTER

TYPE B.R.1a

One of the most recent developments in Marconi Broadcast designs is the production of an inexpensive, low power, high quality Broadcast Equipment suitable for the relaying of programmes transmitted by wire from a remote centre, and intended to function as a unit in a common wave broadcast system. The first of this design, the B.R.1A Broadcast Transmitter to be used in Sweden, is described below.

General.

THE B.R.1*a* Broadcast Transmitter is a self-contained equipment capable of direct operation from 3-phase mains, and of transmitting any selected wave in the band 200/250 metres, with a transmitted frequency of the exceptionally high constancy required by common wave working. Special care has been taken to secure simplicity of control, and warning and tripping devices have been incorporated which automatically secure the maximum of safety for both personnel and equipment. So effective are these that the equipment may safely be left in the casual care of an attendant whose time is mainly occupied by other duties.

Equipment.

The equipment is handsomely housed in a metal cabinet 12 feet long, 3 feet broad and 7 feet high (as will be seen from the photograph). The high frequency and modulation circuits are contained in six screened compartments in the upper part, whilst all switchgear, anode, grid and filament rectifiers for the smoothed D.C. supplies for the various amplification stages occupy the lower part, being positioned most favourably for their individual functions.

Safety gates are provided, which operate in such a manner that when any door is opened the main power is shut off. The general disposition of the components in the cabinet is shown in Fig. 1, the master oscillator and drive circuits being mounted in the left hand top sections, the power oscillator and aerial circuits in the middle sections, and the modulating circuits in the top right hand corner.

As will be seen from the simplified diagram of connections given in Fig. 2, the main power oscillator is driven from a constant frequency master oscillator, and is modulated by choke control from the output of a four stage modulator amplifier.

Crystal Oscillator and High Frequency Stages.

The extremely high frequency constancy stipulated has been obtained by quartz crystal control of the transmitted frequency combined with sensitive thermostat maintenance of the crystal temperature. An alternative crystal and a highly constant valve oscillator, each independently controlled by thermostat, are available

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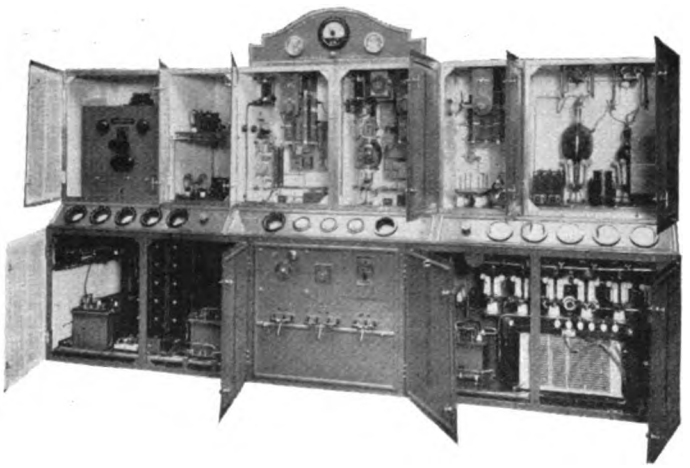
for instant substitution should the necessity arise. Very complete screening from external fields, particularly from the higher power stages, is supplemented by the isolation secured by weak coupling of the output to a screened grid frequency doubler stage operating without grid current. Four magnifier stages, individually screened and neutrodyned, complete the high frequency circuits; the final stage is capacity coupled to the aerial in such a way as to produce effective harmonic reduction.

The circuit diagram of the master oscillator and doubler valve is shown in Fig. 5. It will be seen to consist of a P.610 valve which can be associated with



four alternative circuits by means of a rotary switch. Two of these circuits are designed to cover a waverange of 400 to 500 metres in two steps, and consist of two inductances and a variable condenser. The two inductances are used in series for the longer waves, and one of them is cut out for the shorter waves in the wave-range. The other two circuits consist of crystals which are tuned to twice the required spot wave of the transmitter.

The wavelength of the master oscillator is halved in the next stage of the drive which consists of an S.625 valve which serves as an isolator and doubler stage. This valve is provided with an output circuit which is, of course, tuned to twice the frequency of the master oscillator.

The input and output circuit of this stage, and the circuits of the rest of the drive will be seen from an inspection of Fig. 2.

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The output of the doubler stage feeds into the input circuits of two L.S.5 valves working in push-pull. These valves are neutrodyned in the ordinary manner.

Following this comes one stage of magnification using an L.S.5 valve, and then the final stage using a screen grid valve, the output from which feeds the main oscillator, a D.E.T.3 valve.

The high frequency circuits in the case of the drive valves are tuned with condensers and variable inductances, and are all neutrodyned. The output circuits of the last stage of the drive and of the power oscillator are tuned by a variometer and tapped inductances. A capacity coupled aerial system is employed, and a switch is provided so that the normal aerial can be replaced by an artificial aerial consisting of variable inductance capacity and resistance in series to enable adjustments to be made.

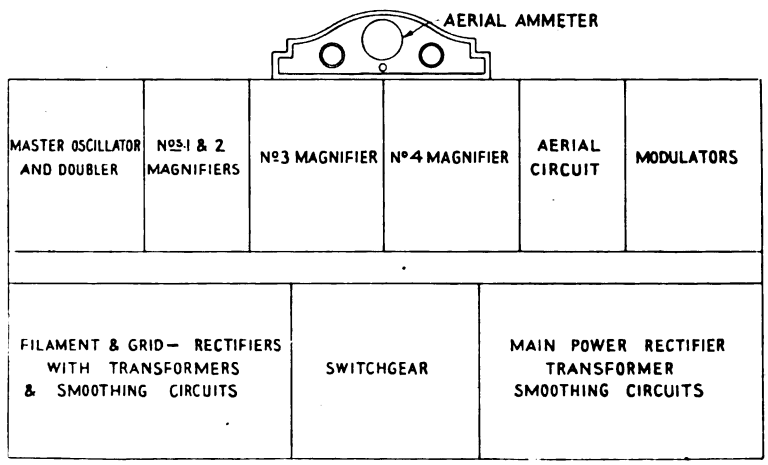

FIG. 1.

Modulator Stages.

Modulation is effected by choke control of the main oscillator. As the available input from the line is likely to be rather small, a four stage resistance capacity coupled modulator is provided, which is able to amplify a line signal of less than ·3 volts to a value capable of completely modulating the final radio frequency stages by choke control and of producing aerial circuit inputs of either 250 watts at 80 per cent. modulation, or 200 watts at 100 per cent. modulation with the highest broadcast performance in linearity and response. As will be seen from Fig. 2, the line is terminated by a transformer, the primary of which is designed for a line of 600 ohm surge impedance. The secondary is bridged by a resistance, a tapping from which is taken to the grid of the first modulator amplifying valve, an L.S.5B. The speech input is thus controlled by this potentiometer, and the latter can be adjusted to give the required depth of modulation and compensate for variation in speech lines.

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This first stage is followed by a similar stage, also employing an L.S.5B. valve. Both of these stages of amplification are housed in a separate screened box, which is situated on the left hand side of the modulator cabinet. Grid bias for the two valves is taken from a battery.

The two following stages of amplification are mounted in the modulator cabinet, and consist of a D.E.T.2 and M.T.9L. valve, the output of the latter being taken to the main oscillator anode. Grid bias for these stages are taken from the main grid bias supply to the transmitter, which is derived from rectified A.C.

All the modulator stages are resistance capacity coupled in the normal way.

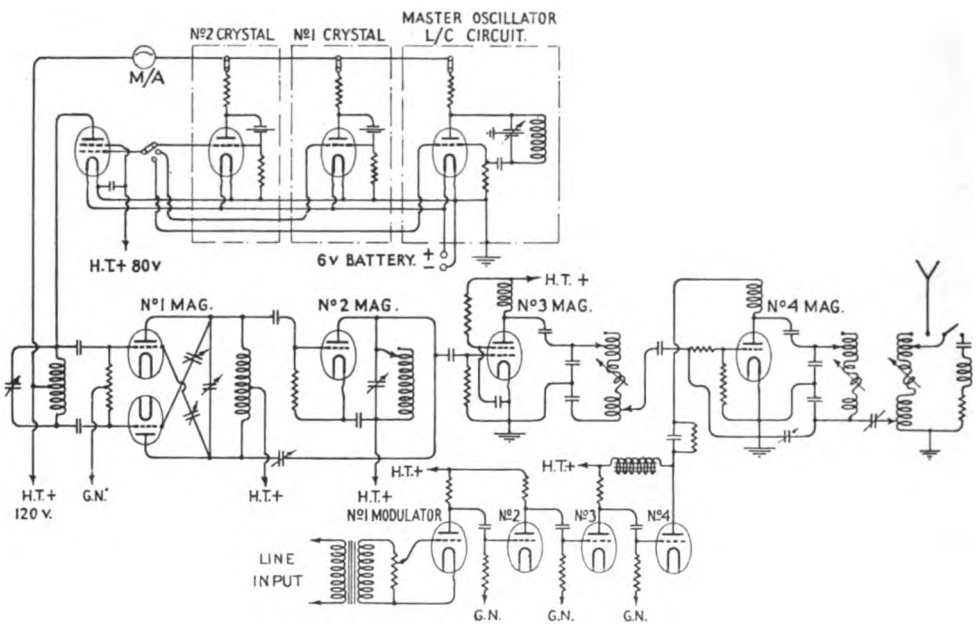

FIG. 2.

Protection Devices.

Protection of radio and modulator circuits during operation is provided by an aerial underload relay and an over modulation indicating and tripping device.

The aerial underload relay is combined with the aerial ammeter, occupies a prominent position in the installation, and trips the power input if any disturbance (such as valve failure) causes a diminution of aerial current. It can be set to trip on small reductions of current.

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The over modulation device includes a sensitive relay operated by the output current of a small rectifier working off the modulated anode voltage of the final transmitter stage. The relay is mechanically biassed against operation by normal modulation voltages, but is rendered sensitive by the nature of its circuit to over modulation peaks. Under such conditions its contact closes a lamp circuit, and the extent of lamp flicker is an indication of the amount of over modulation. The energy of the over-modulation peaks is also used to heat up a thermostat which is set to trip the power supply when over-modulation of excessive amount is experienced.

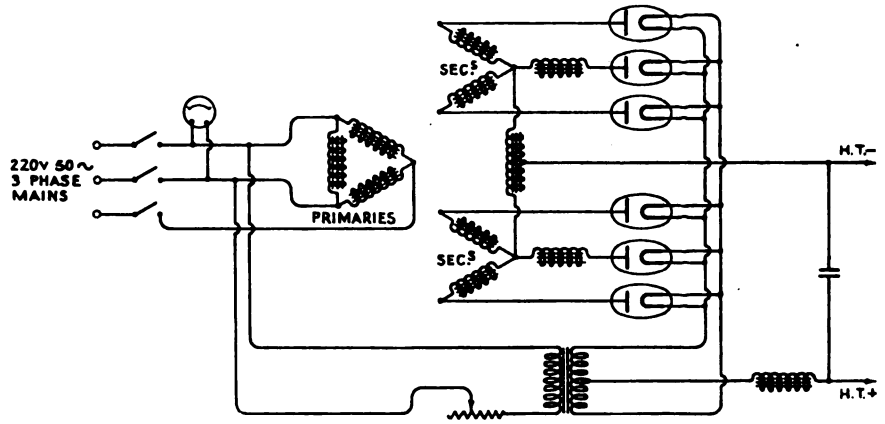

FIG. 3.

Power Supply.

The circuit of the main power supply system is shown in Fig. 3. Filament grid and anode power for the various amplification stages of the set are obtained from rectifiers operating from the 3-phase supply. To secure a steady voltage for filament heating in spite of wide mains voltage variations, floating batteries are used across each of the two filament supply rectifiers. For the same reason,

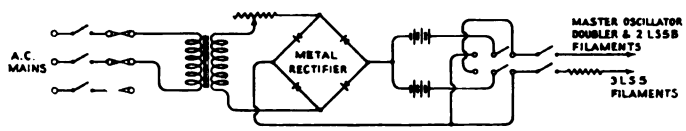

FIG. 4.

crystal valve high tension and filament heating for crystal valve, doubler and valves of the first two modulator stages are obtained from small independent batteries. The independent filament battery is interchanged daily by a switching operating with a similar battery floating or lightly charging on one of the filament rectifiers,

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Fig. 4. In this way a constant condition of charge is maintained. The crystal valve anode battery is a small dry cell unit. Means exist in the transmitter for the automatic maintenance of the state of charge of all batteries, and for independent charging where required.

The main high tension D.C. power supply (4,000 volts) is obtained from a 3-phase valve rectifier working on the 3-phase double Y system. All other supplies are given by dry metal rectifiers on a single phase system. Rectified supplies for all purposes are at 4,000 volts, 500 volts, 450 volts, 20 volts and 6 volts.

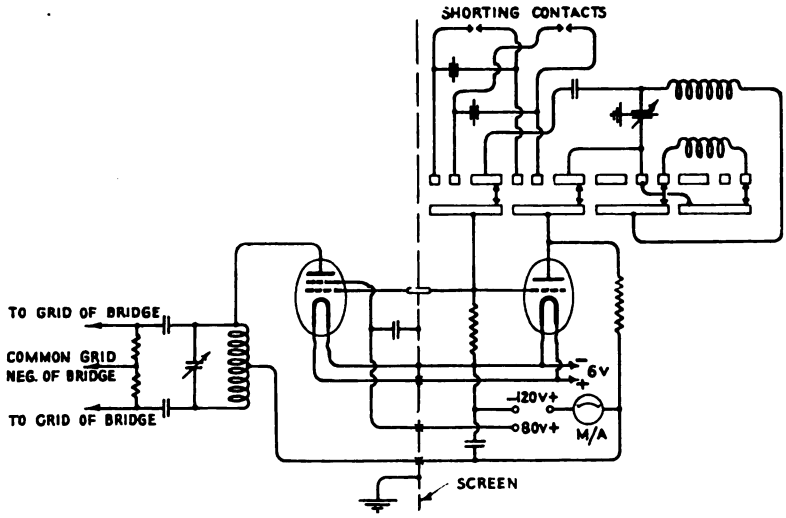

FIG. 5.

Operation.

Operation of the transmitter for starting, stopping or battery charging is simply and safely effected by the manipulation in proper sequence of a few switches centrally located on the transmitter unit. Electrical interlocking secures the safety of the equipment against incorrect sequence of operation. Operation includes continuous maintenance of thermostat circuit supplies to ensure constant crystal temperature, daily reversal of main filament polarity by reversing switch, and daily interchange of 6 volt batteries, together with the usual starting and stopping operations.

After being skilfully set up and adjusted, this equipment may be left for lengthy periods in the care of an attendant who is required only to carry out the manipulations above, and to note and report on the indications of the various protective devices.

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THE MARCONI-ADCOCK DIRECTION FINDING AERIAL

In THE MARCONI REVIEW *for June,* 1930, *a short description was given of a practical Direction Finder which is free from errors caused by "night effect," and some results obtained with it were illustrated.*

In the following article the theoretical principles involved in the design are discussed, and it is shown that the results obtained are in accordance with these principles.

IN a recent article Mr. N. E. Davis has described the adaptation for Medium wave Direction finding, of what is generally known as the Adcock Direction Finder. The purpose of this is to eliminate the errors prevalent at night, and the success of the device is amply illustrated in his curve shown in Fig. 7 of his article. Although these results speak for themselves, there may still be some doubt as to how and in what condition such results could be repeated.

There is always some suspicion of an isolated result unsupported by any theoretical justification, especially in view of the fact that in certain quarters it has been stated that such justification is entirely lacking. Put crudely it has been stated that the arrangement as described cannot possibly work.

The present article is in the nature of a "special pleading" for the system.

In its elementary equivalent form, the aerial is of the simple U shape with the horizontal member shielded in a copper tube and earthed, as in Fig. 1. Such a system to be a perfect direction finder should receive nothing when the plane of the U is perpendicular to the plane of the ray, even when the wave is wholly polarised with the electric force in the horizontal plane. Consider the arrangement set up in this manner.

The E.M.F.s in the vertical members cancel since they are equal and in phase and acting in opposition in the circuit A B C. The horizontal electric force remains, which acting on the copper tube Feeder shielding the inner conductor sets up currents and charges on it. There can be no doubt that if the tube is thick enough and of good enough conductivity so that $2\sqrt{\sigma\lambda c}\,\frac{t}{\lambda}$ is a large quantity

Where t = thickness of wall
σ conductivity of copper
λ wavelength

the inner conductor will be entirely shielded from the direct effects of the currents and charges on the outer conductor. (A simple experiment can be performed by enclosing the inner conductor wholly in the tube when it will be found that no signal leaks through.)

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The currents and charges on the shield can however act indirectly on the vertical aerials, on account of the effective coupling between this feeder and the vertical aerials, so that even though the horizontal wave field cannot act directly on the complete aerial it can act indirectly and produce a signal by induction from the charges and currents set up in the feeder.

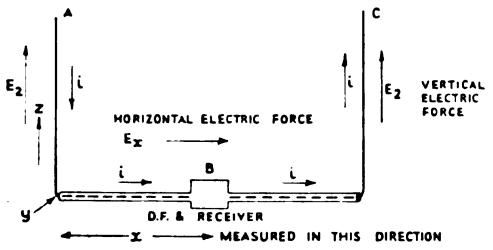

FIG. I.

In the first place it should be noted that the *currents* in the shielding tube are *horizontal* and on this account can produce no E.M.F. in the *vertical* aerials. For a varying horizontal current can produce only a horizontal E.M.F. according to the relation.

$$E_x = \frac{d}{dt}\int dx \frac{[i]t = -\frac{r}{c}}{r}$$

$$E_y = O$$

$$E_z = O$$

i being the current in the horizontal direction.

There remains only the effects of the charges which produce vertical electric forces of the form

$$E_z = \frac{d}{dz}\int dx \frac{[e]t = -\frac{r}{c}}{r}$$

(z measured in the vertical direction).

If the charges consequent on the oscillations set up in the shielding conductor can be reduced to zero by any means, the system will be a perfect D.F. and be free from night errors which, as is well known, are caused by the horizontal field in the wave. If the horizontal shielding members are open-ended, oscillations are set up by the horizontal electric force. The currents are then a maximum in the middle and the charges at the end. Such an arrangement, *i.e.*, an open ended feeder is very little use for eliminating night effect, since the voltages at the end of the shielding members are transferred to the vertical aerials.

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If the ends of the feeder tubes are earthed and the distance between the vertical aerials a small fraction of the wavelength, the system feeder and earth connections, is, in effect, a small untuned frame, the area of which is approximately equal to the length of the feeder multiplied by its height above the ground. Circulating currents will be induced in it by the horizontal electric force or by its equivalent the horizontal magnetic field in the vertical plane of the rays.

These can induce E.M.F.'s in the vertical aerials of the main receiver only on account of the short vertical earthing strips at the ends of the feeder (as we have seen before the horizontal currents produce no effect).

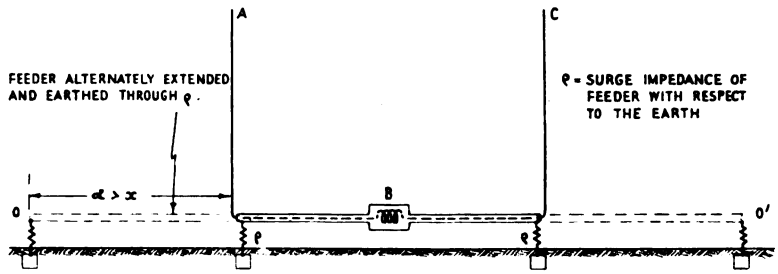

FIG. 2.

The height of the feeder above the ground should be a minimum and it should preferably be buried in the earth if this does not involve too much labour. In certain cases however (where a short wave direction finder is required) it is not convenient to keep the distance between the aerials a small fraction of the wavelength and in such conditions it is more accurate to consider the feeder-earth system, as a cable.

For simplicity consider in the first case the feeder extended to infinity in both directions. When acted on by a uniform periodic horizontal E.M.F. the resultant is a uniform periodic current along the outside of the feeder.

Since the charge at any point is proportional to the gradient of the current, which is zero, the charge is everywhere zero. It is well known that the equivalent of an infinitely extended cable is a finite one terminated by the surge impedance.

The arrangement Fig. 2 is therefore equivalent to the infinitely extended cable and since there is no accumulation of charge (periodic) on the feeder it should produce no indirect action on the aerials.

It will be remembered that periodic charges accumulate at or near the reflection points of such a cable. Now this feeder considered as a cable will have attenuation, let x be the distance at which any disturbance is reduced to less than 1 per cent. of

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its original value. Then if the feeder is extended beyond the aerials a distance large compared with x, any accumulation of periodic charge due to lack of accurate termination will be confined to regions well beyond the vertical aerials and will produce little effect.

Burying the feeder serves a double purpose ; it effectively reduces the area of the frame coupled to the vertical aerial and secondly it greatly reduces the attenuation distance x on account of the extra attenuation produced by the earth leakage.

The arrangement of using a buried cable extended some distance beyond the vertical aerials should therefore be very effective and specially applicable to short wave direction finders where the elimination of the horizontal E.M.F. offers greater difficulties. In the longer wave cases where the horizontal E.M.F. at or near the surface of the earth is always small compared with the vertical forces the arrangement with feeders earthed at their ends should suffice unless the resistivity of the ground is particularly high.

This is the case in justification of the behaviour of the Marconi-Adcock type of D.F. It will be observed that the conception of the " Potential " of the feeder in any part of the argument has not been used, for as is well known there exists no potential function in the case of a varying electromagnetic field. Everything is explained in terms of the currents and charges on the feeder which can be definitely specified. The misuse of the idea of the potential of the earth had been responsible for the argument that the system cannot eliminate the horizontal component and for this reason it is not considered valid.

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MARCONI NEWS AND NOTES

MARCONI ROTATING BEACON TRANSMITTERS.

MARCONI'S Wireless Telegraph Company Limited has now acquired from the British Air Ministry the full rights and drawings for the design and erection of wireless beacon stations of the rotating type.

For many years the Marconi Company has specialised in the design and production of wireless direction finding equipment, both transmitting and receiving. Marconi omni-directional fixed beacon transmitters have been installed at important coastal points in many parts of the world, and by the acquisition of the commercial rights for the rotating type of beacon station in addition, the Company is able to provide what in certain cases will undoubtedly prove a valuable alternative as an accurate aid to both aerial and maritime navigation.

First Contract for Rangoon.

Experimental rotating beacon stations have been erected at Orfordness, Gosport and Farnborough, which, after having been submitted to rigorous and exhaustive tests by the Air Ministry, the Radio Research Board, and other authorities, have been the subject of very favourable reports.

The first station of this type to be built as a commercial contract is to be erected by the Marconi Company at Rangoon, to the order of the Rangoon Port Trust, as a guide to shipping using the busy channel to and from the principal port of Burma.

A special feature of the rotating beacon system is that it requires only an ordinary wireless receiver and a stop watch to enable a ship or aircraft to take bearings, and it is therefore likely that the system will prove of considerable value in augmenting still further the application of wireless to navigation, especially in connection with the smaller classes of ships.

Method of Operation.

The system makes use of a vertical closed loop aerial rotating at a uniform speed of one revolution in 60 seconds. The radiation from such a loop is at maximum in the plane of the loop and at minimum or zero at right angles to that plane.

For the calculation of bearings, two distinctive signals—a " north signal " and an " east signal "—are transmitted at regular intervals as the loop aerial rotates, the periods between them being occupied by a steady dash. The normal method of observation at the wireless receiving station is to start a stop watch at the moment the north signal ends, after which the time taken for the zero signal to be reached will indicate the bearing of the observer from the beacon. If, however, the observer is practically due north or south of the beacon he may not be able to read the north signal owing to the directional effect of the transmission, in which case the east signal is taken as the basis for calculating the bearing.

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It is evident that, the speed of rotation being one revolution per minute, the number of seconds from the reception of the north signal to the reception of the minimum signal multiplied by six gives the bearing in degrees. The necessity for calculation can be avoided by having a stop watch graduated in degrees.

The Rangoon Installation.

The rotating beacon to be erected by the Marconi Company at Rangoon will be similar to the station just built by the Air Ministry at Farnborough, which is of the most recent design and incorporates a number of new improvements.

It will operate on the wavelength of 1,050 metres (285 kilocycles) with a maximum power of 2 kilowatts to the anodes of the transmitting valves.

The system of operation will be to transmit a series of signals commencing at 5, 20, 35 and 50 minutes past each hour, the first minute of each transmission being utilised for signalling the identification letters of the station, VUR.

As practically all ships of any size using the port of Rangoon are fitted with wireless receivers, it is considered that when navigators have become accustomed to the operation of the rotating beacon it may be possible to dispense with the lightship which at present serves the channel for navigation purposes. Thus wireless will take the place of visual observation.

Fixed Beacons for Uruguay.

THE Marconi fixed omni-directional type of wireless beacon station, the navigational value of which has been proved by great experience, is by no means superseded by the rotating beacon, as is indicated by the fact that three new automatic wireless beacon stations of the former type are to be erected on the Uruguayan coast by the Marconi Company on behalf of the Hydrographic Department of the Government of Uruguay. The stations are expected to be placed in commission in the summer of 1932, two being installed in lighthouses—at Lobos Island and Cape Polonio—and the third in the English Bank Light Vessel.

Each transmitter is designed to operate on two definite wavelengths, one of 600 metres and one between 950 and 1,050 metres. Normal operation of the beacon signals will be on the higher wavelength in each case, but a telegraph keying circuit has been incorporated so that in case of emergency or special need the beacons can be used as wireless telegraph stations, and in this event the 600 metre wavelength would be necessary to communicate with ships and coastal wireless stations. Three Marconi Type R.G.27 receivers have also been supplied, so that if necessary complete transmission and reception services can be carried on, a feature which might prove of considerable value on lonely and isolated coast lines.

Sound Signal Combination.

In addition, the Marconi beacon in the English Bank Light Vessel will operate in conjunction with a submarine sound signalling device so that navigators can

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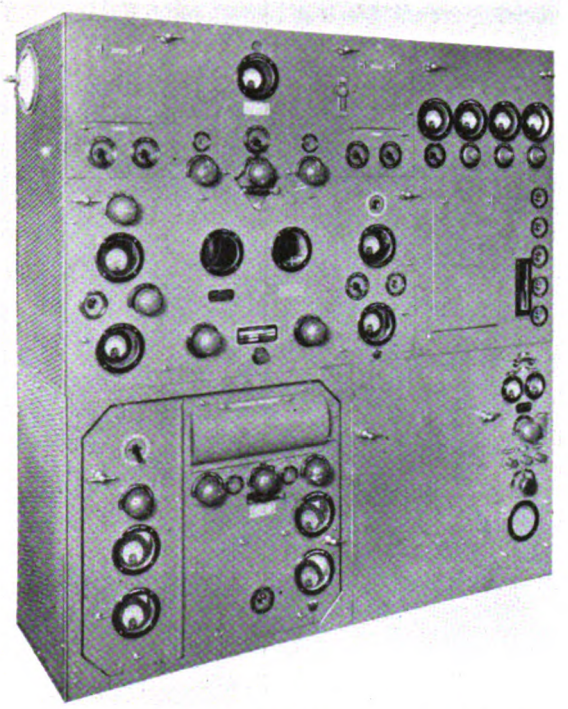
estimate their distance as well as their direction from the light vessel. The submarine sounding device is to be fitted by the Marconi Company, and arranged so that at stated periods the wireless beacon and the submarine sound oscillator will transmit simultaneously a series of dots at regular intervals. By counting the number of dots received by wireless before hearing the first dot transmitted through the water with the speed of sound (4,800 feet per second in water), the navigator can easily compute his distance from their source.



Marconi short wave telephone transmitter on "Monarch of Bermuda." (*See page* 28.)

Iceland Broadcasting Station.

THE high power broadcasting transmitter supplied by the Marconi Company to the Government of Iceland, which was put into commission early this year, has proved very successful. The station, which is built on a site approximately six miles from Reykjavik, was erected to replace a low power broadcasting plant which had been in operation for some years, and it has greatly increased the broadcast service area.

The transmitter, which is of the Marconi P.A.13 type, embodying the latest improvements in broadcast technique, is capable of working on any wavelength between 1,050 and 1,300 metres, but the normal broadcast wavelength used will be 1,200 metres. The aerial rating is from 13—18 kilowatts, depending on the depth of modulation with a maximum of 100 per cent. The aerial is suspended from two 150 metre insulated steel masts.

Programmes are provided from a modern broadcasting studio located in Reykjavik.

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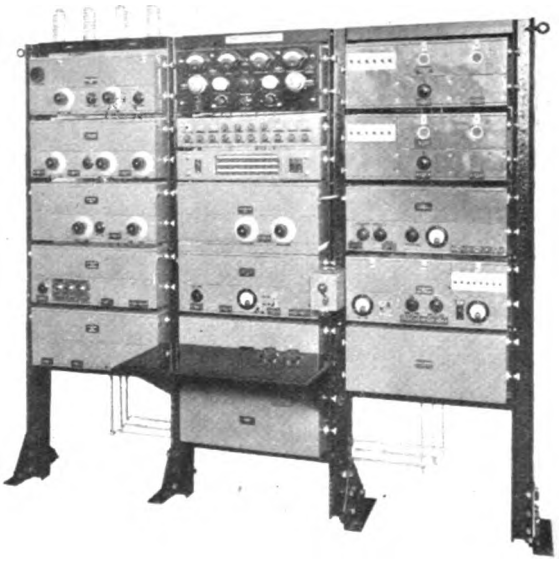
Ship-to-Shore Telephony.

THE new luxury liner " Monarch of Bermuda," which will take her place on the New York-Bermuda run when she is completed, is the latest passenger ship to be equipped with special Marconi wireless telephone apparatus. This will provide an efficient means of communication with the wireless telephone stations at New York and Bermuda, and through these stations the ship will be linked with the telephone systems of the world. Bermuda already possesses a very efficient wireless telegraph service with the North American continent and the West Indies, and wireless telephone apparatus, operating on the Marconi Beam system, is being installed to provide telephone subscribers of the Island with an equally efficient wireless telephone service to New York and ships at sea. At New York telephone calls from Bermuda and from ships at sea can be connected to the telephone systems of the world. These facilities will be greatly appreciated by business travellers and tourists who will thus be able to keep in constant wireless telephone touch with New York from the ship and from land when they visit Bermuda.



Marconi short wave telephone receiver on " Monarch of Bermuda."

Marconi Band Repeater Equipment.

The " Monarch of Bermuda " will also carry a Marconi Band Repeater installation which will be unique both as to the extent of the installation, and in the choice of entertainment available. A total of 39 loud speakers will be installed, distributed between private suites, public rooms and dancing spaces on deck. To provide programmes, a selection can be made from entertainment received from wireless broadcasting stations ; from the ship's orchestra—the music of which is picked up by microphone and distributed throughout the ship from a central amplifier ; or from music and other forms of entertainment by gramophone records. A control is fitted at each loud speaker position to regulate the volume from the loud speaker and to switch on or off as desired.

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Standard Frequency Transmissions.

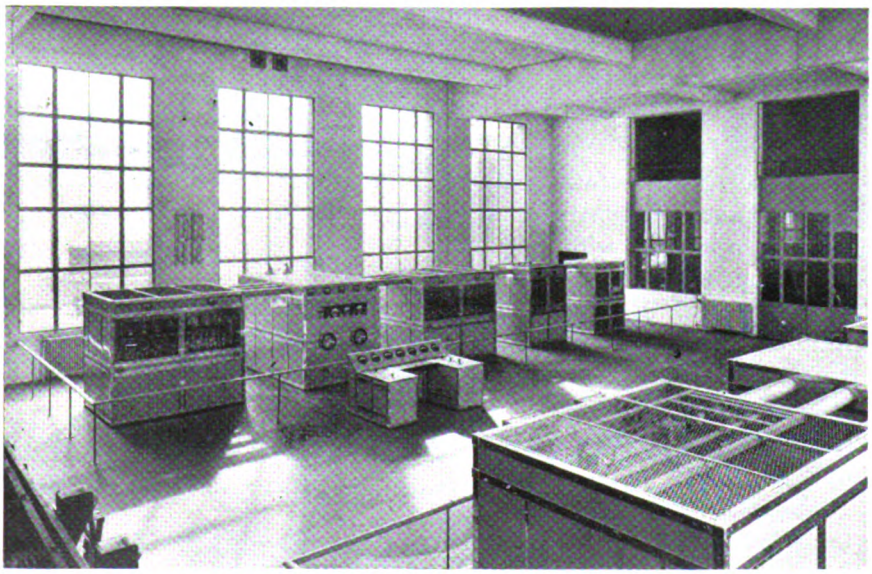
WE are asked by the Department of Scientific and Industrial Research to publish the fact that, at the request of the Post Office, arrangements have been made for additional standard frequency transmissions to be sent out by the National Physical Laboratory on the first Tuesday in the months of September and December of this year commencing at 9 p.m. G.M.T.

The standard transmission is preceded by the announcement " CQ de G 5HW " repeated several times. This announcement is followed by the standard wave transmission on 1,785 kilocycles (168.6 m.) in the form of a continuous dash, the whole lasting 10 minutes.

This procedure is repeated six times, *i.e.*, at 2100 (9 p.m.), 2110, 2120, 2130, 2140 and 2150 G.M.T.

British Regional Broadcasting.

THE second British Regional Broadcasting station has now been opened. It is situated at Moorside Edge, near Huddersfield, in Yorkshire, and is intended to cover the North of England. It is fitted with two Marconi P.B. high-power transmitters, which were manufactured at the Marconi Works at Chelmsford. They are similar to those installed in the first British Regional station at Brookman's Park, near London, and embody the most advanced ideas and the latest refinements



Transmitter hall at the North Regional broadcasting station of the British Broadcasting Corporation.

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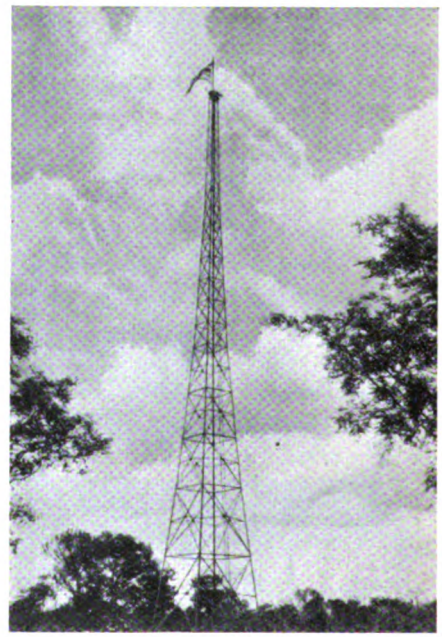
in broadcasting technique. The power of the new transmitters is from 50 to 75 kilowatts (C.C.I.R. rating), depending on the adjustments made.

The power of the new station is reported as " amazingly good " and the station " easy to tune in," while listeners have also been impressed by the uniform quality of the transmissions.

Wireless Communications for Africa.

FOR the establishment of a comprehensive system of wireless communications in Africa, the Marconi Company has received orders for the erection of a chain of wireless transmitting and receiving stations through the heart of that continent. The stations have been ordered by the Administrations of Uganda, Kenya Colony, Tanganyika, Northern Rhodesia, Southern Rhodesia, and the Union of South Africa, and they will be used both for the operation of the new Cape to Cairo air route and, in many cases, for general communication.



The highest Union Jack in Rhodesia —on the wireless mast at Broken Hill Station.

The apparatus to be installed, all of which is being manufactured at the Marconi Works at Chelmsford, is of the latest design for transmission and reception on medium and short wavelengths.

By the aid of these stations, linking up all the aerodromes and enabling aircraft in flight to keep in touch with the ground throughout the journey—the aircraft also being equipped with Marconi apparatus—the trans-African aviation service will constitute the most highly organised long distance air route in the world, and at the same time internal and external communications will be greatly facilitated throughout the Continent.

The sites for the stations have now been decided; they are to be in the proximity of

Uganda—Kampala;
Kenya Colony—Nairobi;
Tanganyika—Moshi, Dodoma, and M'Beya.
Northern Rhodesia—M'Pika and Broken Hill;
Southern Rhodesia—Salisbury and Bulawayo;
Union of South Africa—Germiston, Victoria West, and Cape Town.

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The wavelengths used for wireless communication between the aircraft and these stations will be 900 metres, and inter-aerodrome communication will take place on short waves.

For general communications special wavelengths have been allotted to the stations at M'Pika, Broken Hill, Bulawayo, Salisbury, Germiston, and Victoria West.

Marconi Type A.D.18a equipment installed in a flying boat.

Indian and African Air Routes.

THREE flying boats of the "Kent" type which have been built at Rochester for Imperial Airways Ltd., for use on their trans-Mediterranean air service between Genoa and Alexandria, serving both the Indian and African air routes, are fitted with the latest design of Marconi apparatus.

The Marconi Company were commissioned to equip the new flying boats with their Type A.D.18a aircraft apparatus, a powerful installation with an independent drive which ensures great constancy of the transmitted wavelength. A highly sensitive receiver incorporating a screened grid valve is used, and it is estimated that the flying boats have a wireless range of up to 500 miles.

Power for the A.D.18a installation is supplied by a wind-driven generator operating in the slip stream of the propellers, and in order to provide for the possibility of operating the wireless apparatus when the flying boat has descended on the water, arrangements have been made so that the wireless generator can be driven by the aircraft gas starter engine. A light mast is carried to support the aerial when the aircraft is at rest, but under normal flying conditions a trailing aerial will be used.

The Marconi Company have also received an order from the Blackburn Aeroplane & Motor Company Limited to equip two 10-seater civil aircraft, in course of construction by that Company for the Air Ministry, with the Marconi Type A.D.6m aircraft apparatus.

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As in the case of the Type A.D.18a installations, the Type A.D.6m sets are operated by wind-driven generators. To enable the wireless gear to be operated when the aeroplanes are on the ground, hand-driven generators are supplied so that wireless communication can be carried on at any time. Light telescopic masts will also be carried to support the aerial during working from the ground. During flight the normal trailing aerial will be used.

New Marconi Station for India.

AS a part of the development plan for Bedi Port, Kathiawar, India, a Marconi coast station for communication with ships at sea is to be installed to the order of the Port Commissioner, Lieutenant-Commander Bourne, R.N.

Bedi Port is under the jurisdiction of His Highness Jam Sahib Shri Ranjitsinhji Vibhaji, who is keenly interested in the progress which is being made in this " Liverpool of Kathiawar," and the new coastal wireless station will be fitted with the latest type of Marconi marine equipment. The order has been placed through the Indian Radio Telegraph Company, Ltd.

The equipment will comprise a Marconi Type M.C.13 transmitter of 1½ kilowatts power and the new Marconi Type 352 receiver. Operating on the interrupted continuous wave system, the Type M.C.13 transmitter incorporates the latest developments of valve transmission and is designed to meet all the requirements of modern telegraph services at sea. It is arranged to transmit on any wavelength between 600 and 800 metres. The Type 352 receiver is a highly selective and efficient instrument covering the exceptional wave range of 15 to 22,000 metres.

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THE MARCONI REVIEW

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No. 32. *Sept.-Oct., 1931.*

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General Editor: W. G. RICHARDS.

PHENOMENA ACCOMPANYING RADIO TRANSMISSION

The following is a translation of an address given by His Excellency the Marchese Marconi on the 11th September, 1930, at Trento, on the occasion of the Nineteenth Meeting of the Italian Society for the Progress of Sciences.

THE subject of my brief discourse is: "Phenomena Accompanying Radio Transmissions." A vast subject and one which would demand for handling, however incompletely, far more time than is at my disposal. I shall therefore speak of some only of the many phenomena which accompany radio transmissions and in a somewhat summary and elementary manner.

The numerous successive discoveries of so many new and interesting facts regarding the propagation of electric manifestations and the study of the properties and behaviour of the space across which electric waves can be transmitted have opened up new, vast and fertile fields of useful research which make us always scrutinize more effectively the boundless horizons of conquest as regards the transmission to any distance on our earth and even beyond, of human thought, of the spoken and written word, of sounds and music, of the remote control of power and perhaps also one day of power itself.

About 29 years ago, to be exact, in December, 1901, I discovered the possibility of transmitting electric waves over very long distances, viz., between Europe and America. This discovery was of great importance not only on the practical side but also on the theoretical, because until then almost all physicists believed that the electric waves discovered by Hertz would behave somewhat similarly to luminous waves and that therefore obstacles and the curvature of the earth would inevitably prevent their transmission along the surface of the globe over distances greater than some tens or hundreds of kilometres.

The success of the first Transatlantic radiotelegraph transmissions, confirming my hypotheses, convinced me that very probably there would be no distances in the world across which the transmission of human thought would not be possible by means of electric waves, without the help of artificial conductors.

Refracting Layers in the Upper Atmosphere.

At that time, however, there was lacking a rational theory explaining how these electric radiations could follow the curvature of the earth and reach the most distant countries. Several physicists and mathematicians (among them Raleigh, who in 1903 read a paper regarding the matter to the Royal Society at London), referring

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to the results which I had obtained at distances of several thousands of kilometres, demonstrated by calculation that such results could not be explained by the phenomenon of diffraction pure and simple.

Other experiments which I was able to carry out in the Atlantic on the s.s. " Philadelphia " during the month of February, 1902, enabled me to discover another phenomenon of a certain importance, viz., that with waves of about 2,000 metres, then employed by me, the distances of transmission were during the night several times greater than during the day, which led one to suppose that the sunlight limited greatly the range of propagation of the electric waves in space. This, in its turn, indicated either an absorption of the energy of the electric waves caused by sunlight, or a variation in the conditions which permitted the said waves to reach the greatest distances*.

The phenomenon was particularly interesting because trials carried out across rather short distances where the curvature of the earth was not concerned, had never given any sign of variations in the intensity of signals or in their range which could be attributed to the effects of sunlight.

The mathematician Heaviside in England and the physicist Kennelly in America were the first to put forward the hypothesis, at once universally accepted, that at a certain height, at that time not well determined, there must exist a state of ionisation of the atmosphere or a conductive layer constituting a kind of envelope concentric to the surface of our globe, which envelope was capable of reflecting or deflecting the electric waves in such a manner as to compel them to follow the curvature of the earth, impeding their radiation and their loss into infinite space.

The hypothesis of Heaviside was studied and amplified by many scientists, among them Poincaré, Raleigh, Thomson, Macdonald, Sommerfield, Zenneck, Eccles, Appleton, Eckersley, and many others. Loewestein, in a paper published in the " Proceedings of the Institute of Radio Engineers," of New York, in June, 1916, expressed the hypothesis of the existence of three layers which could influence the propagation of electric waves, one at a height of 11 kilometres from the earth and the other two at 75 and 220 kilometres respectively. This hypothesis approximates somewhat to the more modern ideas which not only suppose the existence of manifold zones or layers capable of reflecting or bending the electric waves but also that these zones vary in height and distance from the earth at different hours of the day, with the seasons, and according to their ionisation or composition due, in turn, to the effects of light, to the electric and magnetic activity of the sun and perhaps to other causes still unknown†.

The determination of the height of the reflecting or refracting layers has been and continues to be the object of laborious study on the part of patient investigators, among them Breit, Tuve and Dahl, Kenrick and Jen, who have submitted interesting papers regarding the matter to the Institute of Radio Engineers of New York‡.

The influence of these layers or zones would explain the variations of range and of intensity of the various electric waves according as they are propagated

* Proceedings of the Royal Society (volume 70, page 344, 1902).
† Transactions of the Royal Academy of the Lincei, G. Marconi, Vol. 3, page 78, 1916.
‡ Proceedings of the Institute of Radio Engineers, New York, September, 1928, and April, 1929.

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across illuminated or dark zones, or when special conditions of solar activity prevail ; from which it consequently results that the alternation of the seasons and of the light of day with the darkness of night constitutes an element of the very first importance for the determination of the waves most suitable to radio transmissions across given distances.

To-day it is necessary for the investigator into the properties of electric waves and the serious student of the scientific progress of radio communication to keep in touch not only with the work of physicists, mathematicians and electrotechnicians, but also with that of meteorologists and astronomers.

On the other hand it is probable that meteorologists and perhaps also the astronomers may soon in their turn obtain precious information from us, the cultivators of wireless, since the means of research used in the science of radio transmissions is already so powerful and varied as also to enable meteorologists one day to obtain data regarding certain parts of the atmosphere and of space regarding which they possess to-day, very little and very dubious information.

Use of Short Waves for Radio Communication.

The advent of short waves, with their world-wide range of action, has in addition to an incentive, also supplied us with a means of studying such interesting phenomena in a much more complete and exhaustive manner than was at first possible.

Almost everyone now knows that by using the most simple short wave transmitters and receivers, i.e., with waves of a length of from 12 to about 100 metres, it is possible, even with the use of but little electric power, to communicate with Australia and even with the Antipodes when the conditions of the atmosphere or of space are favourable ; while with improved apparatus, employing greater power with the systems of concentration of such power, the so-called beam systems, it is possible to stabilise and maintain almost continuous commercial services at all hours of the day both for radiotelegraph and for radiotelephone transmission, whatever be the distance which separates the transmitting and receiving stations.

This progress obtained with the use of short waves, whose special and valuable properties have been specially studied by me since 1915 and whose practical use I was able to demonstrate and propose as long ago as 1922* have now enabled radio transmissions to overcome the competition of the cables, thus forcing powerful organisations which possess already more than 50 per cent. of the submarine cables of the world to come to an agreement with the international organisation constituted for the use of radiotelegraphy in England.

Modern radiotelegraph and radiotelephone installations have allowed of continually extending, by means of the observation of phenonema of difficult explanation, the studies regarding the transmission of waves ; thus phenomena have been ascertained which are more and more interesting even from the purely scientific side, which study, by reason of the conclusions which might arise from it, is truly fascinating.

The fact that the so-called long waves used for radiotelegraphy did not always follow the shortest route between distant stations was known as early as 1922 by my assistant, Engineer E. Tremellen. His observations were carried out, during a voyage around the world, by means of special transmitting and radiogoniometric

* Proceedings of the Institute of Radio Engineers, Vol. X., No. 4, August, 1922.

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apparatus and they proved that in certain cases these waves preferred to follow a long route equal to about three quarters of the circumference of the globe, rather than the direct and shorter route equal to a quarter of the said circumference. These observations were detailed by me in the report which I read before the Institute of Radio Engineers at New York on the 20th June, 1922*.

This phenomenon has already been used practically for some time at modern stations utilising short waves and employed for very long distance transmissions. In fact the English stations of my beam system which carry on public service between England and Australia transmit the waves by the shortest route, of about 18,000 km. across Europe and Asia, during certain hours of the day, while during other hours the transmission is directed through the longest route of about 22,000 km., across the Atlantic, the American continent and the Pacific Ocean. In view of the velocity of electric waves, which is approximately 300 thousand km. per second, the transmission of signals, even by the longest route, does not, of course, involve any appreciable delay, the reception being, for all practical purposes, instantaneous.

Echo and Multiple Signal Phenomena.

Signals which evidently went completely round the earth were remarked by another of my assistants, Engineer Langridge, in July, 1925, while he was listening at Brentwood, England, to the signals transmitted on a wave of 25 metres from the Poldhu station.

An interesting and accurate study of these phenomena was made in 1926 by Quack, who put on record the frequent recurrence (in short wave radio communications) of the perception of a secondary signal or duplicate of the signal immediately after the reception of the principal signal. From measurements carried out by Quack on the basis of the duration of the interval of time between the reception of the principal signal and the reception of the secondary signal, it would appear that the waves in going round the terraqueous globe cover a course of 41,200 km. The fact that this course is somewhat greater than the circumference of the globe would indicate that the electric waves undergo reflections or refractions between a reflecting state (layer) and the earth, or that they describe a maximum circle around the earth situated at a height of 182 km.†.

It is to be noted that the transmissions which take place with the most distant countries, i.e., those near the Antipodes, are effected very often with greater facility than transmissions with countries at intermediate distances, i.e., relatively nearer. This takes place not only as regards the phenomenon of the convergence of the electric waves at the Antipodes but also as regards the fact that by means of the beam system the waves may be directed by one route or the other at will ; if, for example, the conditions for the eastern route are not favourable the waves may be directed by the western route.

The fact of the convergence of the electric waves at the Antipodes, now reliably proved and already brought into common practice, was foreseen by me 25 years ago when in a lecture to the Royal Institution of London I said that radio transmissions to the Antipodes would be possible with the use of relatively small electric power and therefore with an expenditure proportionally less than that which would be necessary for intermediate distances‡.

* Work quoted.

† E. Quack : Zeitschrift uber Hochfrequenztechnik : 28, 117, 1926.

‡ "Recent advances in Wireless Telegraphy," Royal Institution, 3rd March, 1905.

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A phenomenon which has roused great interest among students is that of the repetition of signals or electric echoes, a phenomenon which takes place specially with waves of a length lying between 14 and 20 metres. These echoes, however interesting they may be from the point of view of scientific research, are not in fact liked in radiotelegraph stations for the reason that the repetition of signals often tends to confuse or at least to render less clear the reception of messages. Much study has also been given on board the " Elettra " and at other stations both to observing the effects of the so-called echoes and to thinking out suitable devices for suppressing them.

The repetitions of signals whose periods of recurrence is shorter than the time necessary for electric waves to go completely round the earth have been studied by Eckersley*, Van der Pol and many other investigators. But there are repetitions of signals or echoes which would indicate routes rather different and in some cases enormously greater than the circumference of the globe. Such echoes have been frequently noticed during experiments with long distance transmission and reception carried out on the yacht " Elettra " and at many other stations where I have carried out researches. I shall mention here chiefly those echoes which have evidently gone through very great distances.

If, for example, by means of a short wave radiator, we transmit at intervals brief impulses or signals, such as the dots of the Morse alphabet, we can often, when the conditions are favourable, hear and also record on a neighbourhing receiver or oscillographic device, after a time which may vary from a fraction of a second to several seconds and even minutes, a faithful repetition of the same signal. This would indicate that our signal, before returning to us, has traversed hundreds or thousands or even millions of kilometres, according to the greater or less shortness of the interval intervening between the transmission of the signal and the perception of the echo.

Cause of Multiple Signals.

It more frequently happens that a first repetition of the signal reaches us, as has been observed by Quack, about a seventh of a second after the transmission of the original signal and that other repetitions then follow with the same rhythm, but getting weaker and weaker ; this would indicate that our signal has gone several times completely round the earth taking just the time required by the speed of electric waves which we know to be exactly equal to that of light.

How are these phenomena explained ?

In the first place, as regards the signals which appear to go complete one or more times round the earth, it has been noticed that the phenomenon occurs when the conditions of space are such as to cause only a minimum absorption of the energy of the wave used and these conditions occur specially in the vicinity of the equinoxes and towards the hours of dawn and of sunset at the observing station.

It has furthermore been possible to ascertain, by the indications of radio-goniometers, which reveal with precision the direction of origin of the waves, that they go completely round the globe following in preference a zone of space exposed to the penumbra of sunlight, the so-called crepuscular zone.

* T. L. Eckersley : Proceedings of the Institute of Radio Engineers, Vol. 18, No. 1, January, 1930.

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In 1928 Professor Stormer of Oslo announced that he had been able to confirm the observations made by Engineer Hals with regard to the existence of radio echoes received several seconds after the transmission of each signal. In view of the fact that the velocity of electric waves is about 300,000 km. per second, it is necessary to suppose that the waves causing the echo traverse in certain cases hundreds of thousands of kilometres. In fact in the course of a lecture given at Edinburgh in February this year Professor Stormer expressed a doubt as to whether some of the waves used in the various transmissions were reflected by the orbit of the moon*.

Studies proceeding from Professor Pedersen and others have shown the possibility that the so-called short waves, used for radiotelegraphy, might in certain circumstances cross the Heaviside space and emerge in interplanetary spaces.

The hypothesis of Stormer is however that these waves are reflected at a great distance from the terrestrial globe by electric strata or by electrons projected by the sun. Electrified particles, which emanated from the sun and happened to be under the influence of the terrestrial magnetic field would be bent round in a toroidal zone at a great distance from the earth. The electric waves radiated by our apparatus after having crossed the Heaviside layer would be shut off and reflected towards the earth by the internal surface of this zone.

According to Pedersen, however, and especially with regard to the echoes whose interval from the original signal is greater than about a minute, it is probable that the waves are deflected or reflected by bands or zones of ions situated outside the influence of the terrestrial magnetic field, endowed with a sufficient density of electrons and capable of producing formations such as to serve as reflectors of the waves, which, after undergoing one or more reflections would return to the earth. It is therefore possible that the echoes with a long interval may be caused by zones or bands of ions which, branching from the sun, extend into space and act on our electric waves at a great distance from the earth.

But there is more still. According to the study published by Pedersen†, to which I would refer those who wish to go deeply into this matter, electric echoes can also be obtained which would indicate that the reflecting layer or zone may even be at a distance of 40 million kilometers from the earth.

Engineer Hals has reported that he has observed these echoes after intervals of 3 minutes 15 seconds and even 4 minutes 20 seconds.

If we always bear in mind the fact that the speed of electric waves is 300 thousand kilometres per second, these observations would indicate that the distance traversed by these waves is 58,500,000 and 78 million kilometres respectively.

Seventy-eight million kilometres! If this is true, what enormous progress has already been realised since the time of my first experiments when these same waves could be perceived at a distance of about 20 metres at the most!

* Proceedings of the Royal Society of Edinburgh, Vol. L., Part II. (No. 15), 1930.

† P. O. Pedersen Det Kgl. Danske Videnskabernes Selskab. Mathematisk fysiske Meddlelelser; IX., 5 Copenhagen, 1929.

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It should however be recalled that some physicists, such as Van der Pol, deny that electric waves can go outside the terrestrial atmosphere and thus traverse enormous distances. They explain the delay in the echo or return signals by the hypothesis that this is caused by a special electronic distribution of the Heaviside layer capable of greatly reducing the group velocity as compared with the phase velocity. But this explanation is contested by several scientists, among them Pedersen. I am rather favourable to the hypotheses of the latter since I do not see the reason why there should be excluded the possibility of waves of a certain frequency transmitted by us crossing the Heaviside or other layers, since these layers are all crossed by a multiplicity of phenomena, effects and waves which reach us from the sun, primarily among them heat and light.

An important study of the theories of the propagation of electric waves has been made and published by Professor G. Vanni*, and an interesting compendium of studies made on the same subject has been compiled by Ing. Raffaele Marsili†.

In order to explain the phenomenon of the transmission of electric waves to long distances on the earth the hypothesis is necessary not only of a single conducting, refracting or reflecting layer but of several of these layers, and in order to explain many echo phenomena it is necessary to imagine yet other layers at distances of thousands or millions of kilometres, capable of refracting or reflecting the electric waves now used in radio transmissions.

Recent observations lead to the belief that the zone in which the electric wave ordinarily travels when it traverses great distances is a function of the length or frequency of oscillation of the wave itself. But of capital importance in this connection is also the angle, with respect to the surface of the earth, at which the waves are radiated or projected by the transmitting stations.

Studies made on this subject and also with regard to the angle of arrival of the waves coming from distant stations have not only facilitated the attainment of still better and more regular communications between distant countries, but have also given us a means of, I would say as it were, exploring electrically the space around us and determining the height and variations of height of the said Heaviside layer, as also of other zones or layers existing at a more or less great distance from the earth, which zones facilitate or impede the transmission of waves of various lengths to definite distances.

Ultra Short Wave Transmission.

As regards the public radiotelephonic transmissions now effected regularly between Italy and Sardinia, I decided to use a very short wave, of less than 10 metres (30.604 kilocycles), which waves were never before used for continuous and commercial services. From measurements effected very recently it would seem that along the route between Sardinia and the Italian mainland, this wave is refracted and contained within a space lying between the surface of the earth and a layer situated somewhat lower than the Heaviside layer. Could this be that already indicated by Loewestein at a height of only 11 kilometres?

* Prof. Giuseppe Vanni: Rivista Radio, No. 2-3, 1929.

† Ing. Raffaele Marsili: Volume Dati e Memorie sulle Radiocommunicazioni. Consiglio Nazionale delle Ricerche.

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At these stations there has also been put on record with certainty, a few days ago, the existence of echoes, never before observed, as far as I am aware, with such short waves.

Observations on the behaviour of waves longer than 10 metres seem to have established the fact that they are not confined to a restricted space near the earth.

The propagation of electric waves over great distances still depends on a series of unknown factors which are being investigated and which have apparently to do with the electric and magnetic forces of the universe, among which we should not forget the *auroræ boreales* and above all our omnipotent sun. Who knows where these investigations will lead us ?

In the modern practice of radio communications echoes have already a considerable importance. If they do not exert a seriously prejudicial effect on radiotelegraphy and radiotelephony they nevertheless exert a deleterious effect on the radio transmission of pictures and in long distance television, because these repetitions of impulses and signals tend to obscure and confuse the pictures.

Eckersley* in one of his papers, deals very extensively with the effect of echoes or multiple signals and supplies graphs which show the effects of this phenomenon which, together with the variations of intensity in the signals, constitutes the principal obstacle to the practical realisation of the new marvel—distant vision or television.

Very important researches on this subject are in progress in many parts of the world and I am certain that the progress recently obtained in the stabilisation of frequencies and in the transmission and reception of beam waves will tend towards surmounting the difficulties which still stand in the way of the practical realisation of long distance television.

Limitation of Present Knowledge.

In conclusion I may say that I am very far from knowing how fully to utilise the portentous possibilities afforded to us by electric waves. But our knowledge of the behaviour of these waves, as of that of the space which surrounds us, increases every day, leaving, however, on many of us the impression that in at least equal proportions there also extends the field of knowledge which still remains for us to acquire.

The great conquests already made allow us, nevertheless, to assert now with certainty that by means of electric waves mankind not only has available a new and powerful means of scientific research but is conquering a new force and utilising a new arm of civilisation and progress which knows no frontiers and can even push out into infinite spaces where never before perhaps has the feeling or any manifestation of the activity and thought of man been able to penetrate.

This new force which is taking an ever more decisive part in the evolution of human civilisation is certainly destined for the general good by promoting knowledge of each other among nations, thus favouring peace, permitting us to satisfy more and more an essentially human desire, i.e., to be able to communicate with each other with ease and rapidity, thus annihilating that powerful element of separation which is called distance.

* T. L. Eckersley : Work quoted.

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COASTAL AND HARBOUR WIRELESS SERVICES

The object of the following article is to enlighten readers, more especially those interested in the use of Wireless as a means of increasing the efficiency of Coastal and Harbour Services, as to the research and development work carried out by the Marconi Company in order that their clients amongst the world's Harbour and Coastal Authorities should obtain from Wireless the greatest possible assistance in their task of ensuring the safety of life and property at sea. Equipments in general are briefly described in the article and mention is made of the more recent applications of the Wireless art to marine navigation.

TO afford a means of communication between ships, and between ships and shore, was the first and more obvious application of the wireless art and having turned its attention in this direction almost immediately after Senator Marconi's early experiments had astonished the world, the Marconi Company has well over a quarter of a century's experience of marine Wireless communication to its credit.

Most nations depend to a large degree for their prosperity and importance upon the extent of their sea-borne trade, in the recent phenomenal growth of which Wireless has played no small part. Until the beginning of the present century every vessel was entirely cut off from the rest of the world for the duration of each voyage, yet to-day, any ship fitted with Wireless Equipment, no matter what her position, can maintain communication with one or other of the countless land and ship stations scattered over the surface of the world. Furthermore, there are in existence excellent services for reporting and forecasting weather, and giving time signals and news of which ships may avail themselves. Broadcast entertainment helps to improve the lot of those at sea ; fishing fleets denied the luxury of skilled operating personnel make valuable use of Wireless Telephone communication ; and passengers in the larger liners are in telephone touch with their offices and homes. But important though all these applications of the art undoubtedly are, there can be no question that Wireless confers an equally great boon to shipping in its application to navigation, and hence in the increased efficiency of the services of Coastal and Harbour Authorities.

A recent issue of THE MARCONI REVIEW* contained an article describing the work carried out by the Marconi Company in developing marine direction finding receivers, and the purpose of the present article is to discuss the beacons and other equipments of direct interest to the Coastal and Harbour Authorities, rather than to the mariner, to whom, however, they render service of inestimable value.

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* No. 29, March-April, 1931.

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Direction Finders for Coast Stations.

With the advent of the Valve Amplifier in the year 1915 or thereabouts, the practical development of radio direction finders became possible, soon after which Coastal Direction Finding Stations came into being for the purpose of furnishing ships with directional assistance. Such a station is able to determine to an accurate degree the direction of the signals transmitted from a vessel, and, with the aid of one or more satellite stations, to plot the position of the vessel, which information may then be transmitted to the Captain. Alternatively the observations may be given to the Captain so that the co-ordination of the Bearings can be performed under his supervision.

Although the almost universal adoption of the Marine Direction Finding Receiver, by means of which the Captain may obtain directional observations quite independently of any particular shore stations, has lessened the need for Coastal Direction Finding Stations, these latter are still able to render service of extreme value to such vessels as those having no skilled operating personnel, and they remain, therefore, in considerable demand.

Type has succeeded type from time to time as the Company, in accordance with its general practice, has found it possible to embody new developments in the apparatus. Until recently, however, all direction finders have been unreliable during the period from about an hour before sunset to about one hour after sunrise, a defect of serious import. Now, however, after exhaustive research work, the Company has placed on the market the type D.F.G.8 Direction Finding Receiver, incorporating the Marconi-Adcock methods of night error elimination. Fundamental considerations preclude the development of portable or mobile direction finders featuring night error immunity, and it would appear, therefore, that the Coastal Direction Finder may now gain considerable justification for its continued existence.

The type D.F.G.8, a direction finder employing the Marconi-Adcock system, comprises in the main, four aerials, each suspended within a 70 foot wood lattice tower, and tubular feeders connecting the aerials to the goniometer which forms part of the single instrument unit. Design of the Receiver, which comprises four screened grid high frequency amplifiers, detector, two low frequency amplifiers, an oscillator and a phasing unit, has been most carefully carried out, resulting in an excellent and imposing appearance combined with efficiency of performance and simplicity of manipulation. Two models, differing only in the wavebands they embrace, are available, namely, the types D.F.G.8a and D.F.G.8b, for 500—1,100 and 800—1,800 metres respectively.

The Non-Directional Beacon.

It is probably unnecessary to point out that in order to make use of a marine direction finder, observations may be made on the signals emanating from any

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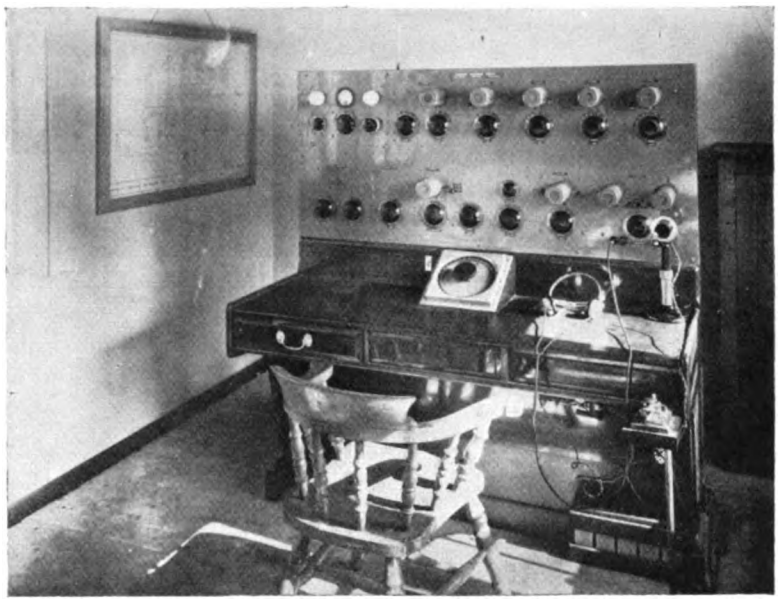
transmitting station whose position is known. The many broadcasting stations, for instance, form excellent beacons, working as they do continuously throughout the greater part of the day and night, but there is, nevertheless, a definite need for beacon stations, whose sole object is to ensure the existence of signals at definite times from known points of reference.



Type D.F.G.8 Marconi-Adcock Direction Finder.

That every country possessing a seaboard recognises its obligations to mariners is evidenced by the navigational facilities freely provided. For centuries these were confined to aural and visual signals, such as lighthouses, lightships, flares, fog-guns, bells, syrens and the like, all of which suffer from the disadvantages of extremely limited range and ineffectiveness in conditions of bad visibility. The development of the wireless beacon has enabled the authorities responsible for these services, to make a tremendous advance in their efficiency, and the existence of some 200 beacon stations in various parts of the world is sufficient testimony to the reception accorded this new navigational aid.

Appreciating from the first that even in the more populous countries, beacon stations would usually be installed in lightships and lighthouses, where skilled personnel would not be available and access for periodical inspection might be difficult, if not impossible at times, the Marconi Company, working in close collabora-

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tion with the foremost authorities, has devoted a considerable proportion of its resources to the development of automatic apparatus and simplified control mechanism, culminating in the type W.B.2b equipment, which may be arranged for entirely automatic starting, stopping, controlling and battery charging, no attention of any sort being necessary beyond the occasional replenishment of fuel and oil supplies. Duplication of running machinery may be a feature if desired, in which case apparatus may be provided for the automatic selection of the correct machine when either is faulty. No fear need be entertained, therefore, that the modern wireless beacon is too complicated for installation in uncivilised localities. Conditions in general could not well be less favourable than those obtaining at the Chinese North Saddle beacon site, yet the Marconi beacon recently installed there, at the instigation of the Honourable Corporation of Trinity House, continues to give the utmost satisfaction.

Provided that it is convenient for an occasional visit to be made by an Inspecting Engineer, a highly efficient service is assured equal to that rendered by the numerous beacons operating around the British coast. The light or other normal staff will quickly gain proficiency in making slight adjustments or at least in reporting intelligently upon breakdowns, which, though rare, can occur with even the finest British machinery.

Having an aerial energy of approximately 350 watts the type W.B.2 Beacon is suitable for most requirements, but a less powerful edition is available for special circumstances.

Obviously a beacon is seldom more desirable than in a lightship, the existence of the one implying a need for the other, and the Company's experience naturally embraces numerous installations in vessels offering very restricted accommodation for apparatus and aerial. The difficulties, however, have never proved to be insurmountable, a 100 watt edition of the type W.B.2 beacon generally meeting the case, the curtailment of power, and hence of the service range, being unavoidable.

Directional Beacons.

Theoretically an aerial system capable of directional reception is equally capable of directional transmission and the Marconi Company's activities have included, not without a considerable measure of success, investigation of the possibilities of evolving beacon apparatus which would at one and the same time furnish the navigator with signals and an indication as to his direction in relation to the beacon.

As far back as the year 1920 the Company installed at Inchkeith, Scotland, the Marconi-Franklin Revolving Beacon, which suffered from the single disadvantage that practical considerations limited the wavelength to 10 metres or less.

With a similar object in view, technical experts of the British Air Ministry have developed a closed, rotating loop transmitter, which, though dating in principle

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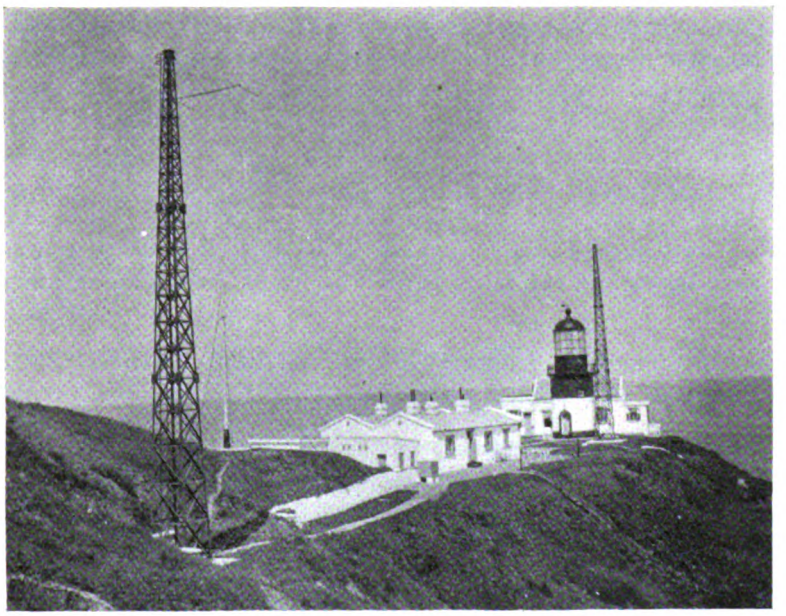
from the time of Hertz, is entitled to recognition as the first practical directional beacon working on wavelengths of the order of 950/1,050 metres and serving all directions equally.



North Saddle Wireless Beacon Installation.

A closed loop unfortunately, is an inefficient radiating system and a very considerable amount of power must necessarily be expended in order to ensure a satisfactory service range of the order of 100 miles. Difficulties in design of frame, brush gear and rotation governing mechanism have now been successfully overcome and irregularities in the transmitted space pattern due to absorption and reradiation by local obstacles have been avoided by the care displayed in the design of apparatus and the building in which it is housed.

Simplicity itself in design, it is, perhaps, desirable briefly to explain the principles underlying the operation of the beacon. The radiated space pattern is, of course, the familiar figure 8 and if the loop is arranged to rotate through 360° in one minute, the distant listener observes, by means of an ordinary wireless receiver alternate minima and maxima at 15 seconds intervals.

Bearings may be taken by means of an ordinary stop watch, preferably calibrated in compass degrees. A characteristic signal is emitted when maximum

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radiation is in the North and South line, upon hearing which the observer starts his stopwatch, stopping it again when signal strength reaches a minimum. The bearing may then be read directly from the compass watch-dial, or, in the case of the ordinary dial, may be taken as six times the reading in seconds. The transmission of a second characteristic signal in the East-West line of maximum radiation provides an alternative datum line for use when the observers minimum signals happen to coincide with the North signal. A moment's consideration will show that this type of beacon suffers from 180° ambiguity, which, however, is seldom troublesome. In common with other directional beacons the rotating loop type has numerous advantages, not the least important of which is that rolling of the vessel in no way affects the accuracy of the observations. Others will readily occur to the reader, but the fact must not be overlooked that the range limitation alone is sufficient guarantee that this new navigational aid can never entirely supplant the marine direction finding receiver.

By co-ordination of two bearings, the second being obtained from a similar beacon or from any other source, the observer can, of course, fix his position.

The Marconi Company is privileged to market a beacon transmitter embodying the experience of the Air Ministry Technical Officials, in addition to the knowledge gained by themselves in their research, experimental and practical work, on all forms of directional transmission and reception. Possessing all the leading features of the well known " Orfordness " rotating beacon, but incorporating numerous refinements, the Marconi Rotating Loop Beacon is assured of a permanent place amongst the navigational aids the Company has been able to place at the disposal of the mariner.

Whilst discussing directional beacons, mention must be made of the equi-signal system, which has not so far been adopted for marine navigation, but is nevertheless worthy of consideration for certain special circumstances.

In brief, this type of beacon is essentially for " homing " purposes, that is to say, its function is to provide a straight path or paths in predetermined directions to and from the beacon. No indication is given as to the bearing of the craft from the beacon and although a certain amount of use might be made of the directional signals by craft crossing the equi-signal path the assistance rendered by the beacon is intended to be reserved to those having to navigate along the equi-signal course, which fact would normally preclude its marine adoption.

The system in its simplest form comprises two loop aerials fixed at right angles to each other, and at 45° to the airway or other desired path, each loop having its own oscillation generator. In operation, the loops emit interlocking Morse characters, that is to say, although both are tuned to the same wavelength " marking " on one

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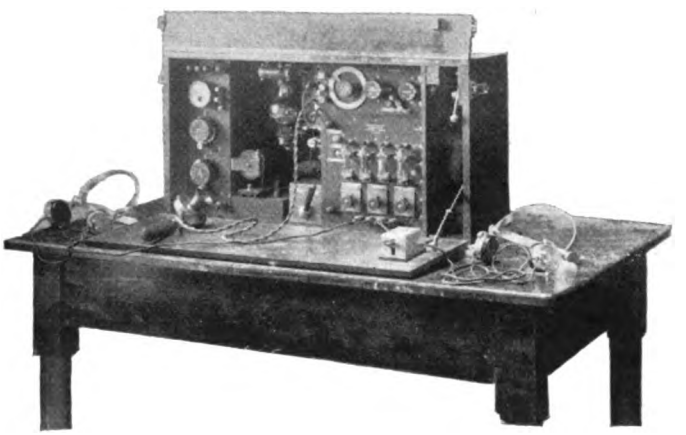
loop is arranged to coincide with " spacing " on the other, so that one or the other is always energised, but never the two at the same instant. Diagramatically the effect is as follows when the letters F and L are used :—

Loop A · · —— · · · —— · · · —— · · · —— ·
Loop B · —— · · · —— · · · —— · · · —— · ·
Resultant · · ———————— ———————— · ·

Clearly the " on course " signal will be a continuous dash of unvarying strength, but deviation to the extent of only 1° or so will be immediately indicated by the ensuing irregularity of strength. This irregularity becomes more pronounced as the deviation increases, until at a few degrees off course, the predominating letter is easily recognised and the navigator is aware of the direction in which to turn in order to regain signal strength equality.



Mersey Dock and Harbour Board Radio-telephone Installation, 1921.

Visual indication of strength equality, or of degrees on or off course, can be arranged by means of suitable equipment at the receiving station working in conjunction with a beacon-transmitter of more complicated design, but as the usefulness of the equi-signal system is almost entirely restricted to aerial navigation, it is not necessary to devote space in this article to a more detailed description of its features.

In passing, however, it is interesting to note that by means of a special radio goniometer the equi-signal zone may be oriented in any desired direction, without regard to the relationship the loops themselves bear to that direction. Moreover by means of a more complicated goniometer in conjunction with a single pair of loops, it is possible to emit a multiplicity of equi-signal zones.

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Lightship, Lighthouse and Harbour Communication Services.

Pioneers in almost every field, the Marconi Company supplied to the Mersey Dock and Harbour Board in the year 1921, telephone communication sets for communication between the Bar Lightship and the Dock Offices, and the Company thus has the honour of having been responsible for the world's first commercial wireless telephone stations.

A simple and reliable means of communication between lightships, lighthouses, tugs, dredgers, pilot boats, shore depots and Seaport Administrative Offices had long been sought, and a variety of methods had been tried without avail. The introduction of wireless as a solution was impracticable before the development of telephony, owing to the fact that Morse reading was beyond the capabilities of the users, often aged seafaring men.

Over a period of several years wireless telephony has proved its reliability and value, if indeed, proof of the latter were necessary, but the continuous attention of the Company has been directed to the problem of developing apparatus so simple of manipulation, that persons lacking entirely a knowledge of the principles of wireless communication, and in fact, without any electrical training whatever, should experience no difficulty in operating the apparatus.

Their success in this direction is reflected in the numerous orders received for the type " X.M." sets, the popularity of which is borne out by letters of appreciation received from almost every corner of the civilised globe.

Three editions rated respectively at 100, 250 and 500 watts complete the " X.M." series, there being comparatively little difference in their general features.

All working parts of the sets are enclosed in metal panels, the transmitter working on a selected fixed wavelength, and the only control accessible to the operator being the handle operating the " send/receive " and battery charging switch, which also stops and starts the motor generator. In addition there are the controls for tuning and reaction adjustments of the highly efficient receiver.

The Calling Device.

In addition to their special application to Harbour Services, the type " X.M." sets have proved to be equally useful for installation in small fishing vessels and lifeboats and for the conduct of point to point services ashore. A definite demand arose, however, for a means of attracting the attention of a station at which a continuous watch cannot conveniently be maintained, and as a result, the Marconi " Call " apparatus was designed.

The latest edition, the type C.g3, whilst suitable for use with any telephone set is supplied more frequently with the " X.M." type of sets than with any other, as

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these are usually installed where no trained personnel are employed and consequently no continuous watch is kept.

The very ingenious construction of the Marconi " Call " Equipment need not be dwelt upon. Suffice it to say that its function is to enable a caller to attract the attention, by means of a bell or other audible signal, of the desired station staff, without, however, having the least effect upon " call " receivers installed at other nearby stations, even though these may be tuned to the same wavelength.

Operation of the device is extremely simple and in view of its extraordinary reliability and virtual immunity from false calls there is no doubt that it has filled a long felt want.

Conclusion.

Special modifications of the equipments mentioned above and various equipments of insufficient general interest to come within the scope of this article, have from time to time been supplied to satisfy special requirements.

For instance, beacon transmitters have been modified to be capable of acting when necessary as ordinary telegraph transmitters. Such a transmitter with the addition of a suitable receiver comprises a complete station for ordinary marine or other telegraphic communication duties, the modifications including provision for changing the wavelength.

Again, a submarine signalling device, which, however, is not of Marconi manufacture, is occasionally supplied by the Company for installation on lightships together with beacons of the omni-directional type. The object of the device is to enable navigators to estimate their distance as well as their direction from the beacon. The wireless and submarine transmitters are arranged to transmit simultaneously a series of regularly spaced dots, which signals reach the observer, in the case of the former, through æther at almost instantaneous speed and in the case of the latter, through water at some 4,800 feet per second.

By counting the number of dots received by wireless before the arrival of the first dot by water computation of distance from the source of the signals becomes simple.

More detailed information regarding any or all of the equipments mentioned and the advice of the Company on special problems are at all times available, but this article will have served its purpose if it proves to be of assistance to Authorities charged with the duty of organizing a new, or modernising an existing service.

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SHIP TO SHORE TELEPHONE INSTALLATION ON THE S.S. EMPRESS OF BRITAIN

The difficulties associated with long distance ship-to-shore telephony, and the methods used to overcome them, are outlined in the following description of the wireless telephone installation in the "Empress of Britain," executed by the Marconi Wireless Telegraph Company, Limited, an analogous installation to that existing on the White Star Liner "Homeric," which was described in the MARCONI REVIEW *No. 30 for May-June, 1931.*

A special feature of the "Empress of Britain" equipment is the ability to speak from the ordinary cabin telephones which are connected to the wireless telephone through the ship's manual switchboard, so that telephone service to or from the ship is as convenient as the normal shore telephone service.

THE development of long range ship-to-shore telephony as a commercial project has been rendered possible by the use of short waves between 16 and 70 metres and has been brought to the present high standard of technical efficiency and organisation, during the past two years, by the Marconi Company in conjunction with the wireless section of the Post Office in England and with the co-operation of the American Telephone and Telegraph Company in America, all of these organisations having erected new stations and provided specialised staff to deal with this service.

The provision of a comparatively high power and good quality duplex Radio Telephone Service, where the transmitter and receiver, with their associated aerials, have to be installed within a few hundred feet of each other, possesses its own particular problems. Some of these may be easily visualised if one remembers that the energy in the transmitting aerial is approximately the same as that used in the first chain of Broadcasting Stations erected by the B.B.C., such as 2 LO London, and similar stations at Birmingham, Manchester, etc., and that to provide a duplex service is equivalent to receiving the distant station while being situated next door to one's local station.

In the case of commercial radio services on shore the transmitting and receiving stations are usually separated by anything from 20 to 100 miles—as in the case of the British Post Office with their transmitting station at Rugby and the receiving stations at Baldock near St. Albans, a separation of approximately 60 miles, and Cupar, Fifeshire, a separation of approximately 350 miles.

Another difficulty in providing a radio telephone service on ship is that the local carrier induces currents in the ship's rigging, ventilators and fan casings, etc., and with the usual loose contacts that exist these currents produce a form of static

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which would spoil reception. The normal vibration associated with a ship must not be neglected or trouble of another form will be experienced.

The above brief outline of the conditions to be met, will assist in following the description of the radio telephone installation on the "Empress of Britain," a schematic diagram of which is shown in Fig. 3.

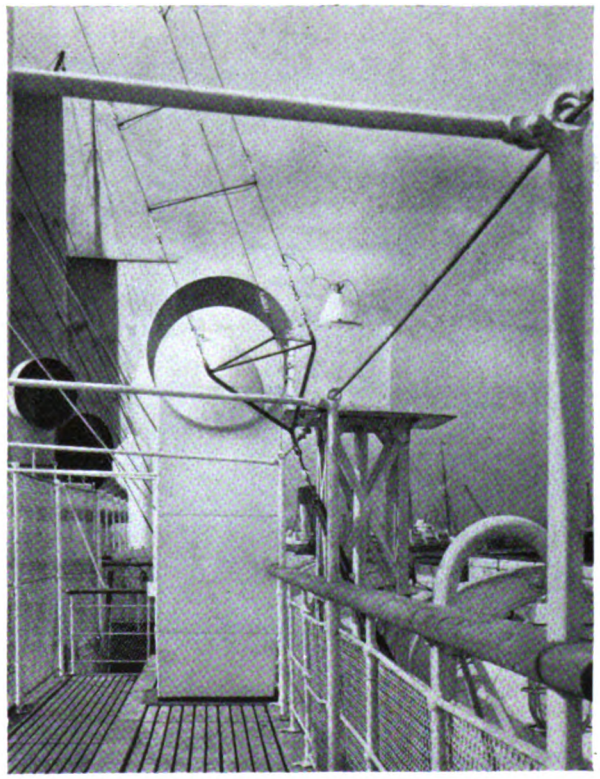

FIG. 1.

General Disposition of Equipment.

The transmitting room is situated on the Sun Deck and partly inside the forward portion of the after funnel and the receiving room is on the same deck between the middle and forward funnels.

The telephone transmitting aerials are slung from the halyard supporting the main wireless aerial in the open space between the after funnel and mast and above the tennis court, while the receiving aerials are slung between the forward mast and the port and starboard sides of the searchlight bridge, below the navigating bridge.

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Radio energy is conveyed to and from these aerials by means of concentric copper tube feeders an arrangement which provides complete protection to passengers and crew as the outer tube is at earth potential and completely encloses the "live" conductor. The energy loss in this type of feeder being very low, the length employed is a negligible factor and allows the most convenient positions to be used for housing the apparatus while the aerials are erected in the most suitable position from a technical viewpoint.

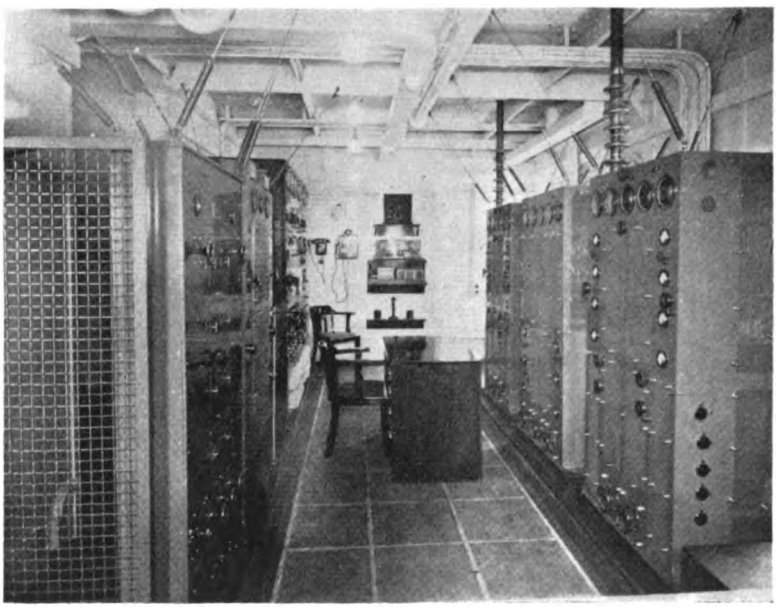

FIG. 2.

The aerials used are mainly of the Franklin omni-directional type, Fig. 1, but those for the shorter wavelengths have a definite area of concentration in the vertical plane.

Power for the transmitter is drawn from two motor generator sets driven from the ship's mains and located in the main switchboard room of the vessel but started and controlled from the telephone transmitting room. One generator delivers 22 volts direct current for heating the filaments of the power valves in the transmitter and modulator panels and for charging the 6-volt batteries used for heating the filaments of the Master Oscillator valves. The second generator supplies 500 volts alternating current at 500 cycles from which all other necessary supplies are obtained through suitable transformers and rectifiers.

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Transmitting Room.

The apparatus in the Transmitting Room is contained in five separate units and is shown in Fig. 2. All units are of such a size that they will pass through the standard doorway of a ship's cabin without dismantling. On the left of the photograph are shown the switchboard controlling the two generators with the respective distributing switches, the main rectifier panel for the provision of the 5,000 volts D.C. required for the anode supply to the main power valves, and a second panel containing four small rectifier units for the provision of anode supply to the master oscillators and the various grid bias supplies.

On the right of the photograph are the two short wave oscillator panels with a common modulator panel in between. All panels are of the latest pattern and of the fully enclosed protected type, automatic trip switches being incorporated where necessary to protect the staff from accidental shock. A special felt base on which the panels are mounted insulates them from the mechanical vibration common to most ships and any vibration existing is further damped by means of adjustable spring tension devices between the four top corners of the panels and the roof of the cabin.

Both oscillator panels are identical in appearance and general construction, the only difference being in the wave band covered. One oscillator covers from 12,180 kilocycles to 14,100 kilocycles, or approximately 21·2 to 24·6 metres, and the second from 4,060 kilocycles to 4,640 kilocycles, or approximately from 65 to 74 metres, without the use of plug-in coils or switches.

These wavebands are sufficiently wide to provide the necessary channels for the various services required and to provide for further extension of these services. The 21 to 24 metres transmitter is normally used for long distance daylight communication and the 65 to 74 metres transmitter for night and short distance communication.

Air-cooled valves are used in all stages.

The required steadiness of frequency is obtained from a master oscillator situated in the right hand lower corner of each oscillator panel and consists of two separate units. The lower unit contains the oscillatory circuit and is supported in a rubber-lined cradle as a further protection against vibration. A novel form of valve oscillator circuit is used and the frequency is unaffected by normal changes of low tension or high tension supply. The circuit is self-compensating against temperature changes and the use of ovens with thermostatically controlled heaters common to most other forms of frequency control is avoided. The main condenser of this unit is provided with a vernier scale, and a calibration chart is supplied which permits the operator to set the transmitter to any required frequency within its range or to change the frequency as required.

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The second unit contains the necessary amplifying and frequency changing stages until sufficient energy is obtained to drive the first power stage at the operating frequency.

The three power stages are all of the same general type, being capacity bridge balanced circuits with fixed inductive coupling between stages and a novel form of unit construction for the closed circuits.

One M.T.12 valve working at approximately 30 watts input is used in the first power stage and a single M.T.9F valve with approximately 100 watts input for the second power stage, while two M.T.9F valves working in push-pull with 2 kilowatts input are used for the final stage.

With this power in the final stage approximately 1·5 kilowatts of aerial energy is obtained with the transmitter unmodulated.

To avoid the highly damped disturbances produced by the local carrier exciting various radiating circuits in the rigging and other ship's fittings, and producing noise in the local receiver, a voice-operating carrier controlled system is fitted.

This consists of a direct current amplifier system by means of which the subscriber's voice controls the anode supply to the first two power stages, thus controlling radiation from the final power stage. This system maintains the local transmitting aerial in a quiescent condition until modulation is supplied. As the switching-on occurs at almost infinite speed no audible clipping of initial syllables occurs and the speed of switching off when modulation ceases is adjustable at the monitor board over a fairly wide range.

The modulator panel for the system of high power modulation in use consists of three stages with resistance capacity coupling between stages. The first stage consists of a single M.T.4B valve with 25 watts input, the second stage a single M.R.6B valve with 60 watts input, and the final stage four M.T.9L valves in parallel with a total input of 2 kilowatts.

The frequency response of this modulation system is practically flat from 50 to 7,000 cycles and 92 per cent. modulation can be applied without appreciable distortion.

Receiving Room.

The apparatus in the receiving room is mounted in two separate units and is shown in Fig. 4. The right hand unit contains the radio frequency circuits and the left hand unit the audio frequency circuits with terminal and monitoring equipment. Both units are mounted on floating floors with spring damping to roof as in the transmitting room, but the floors are of a slightly more elaborate design.

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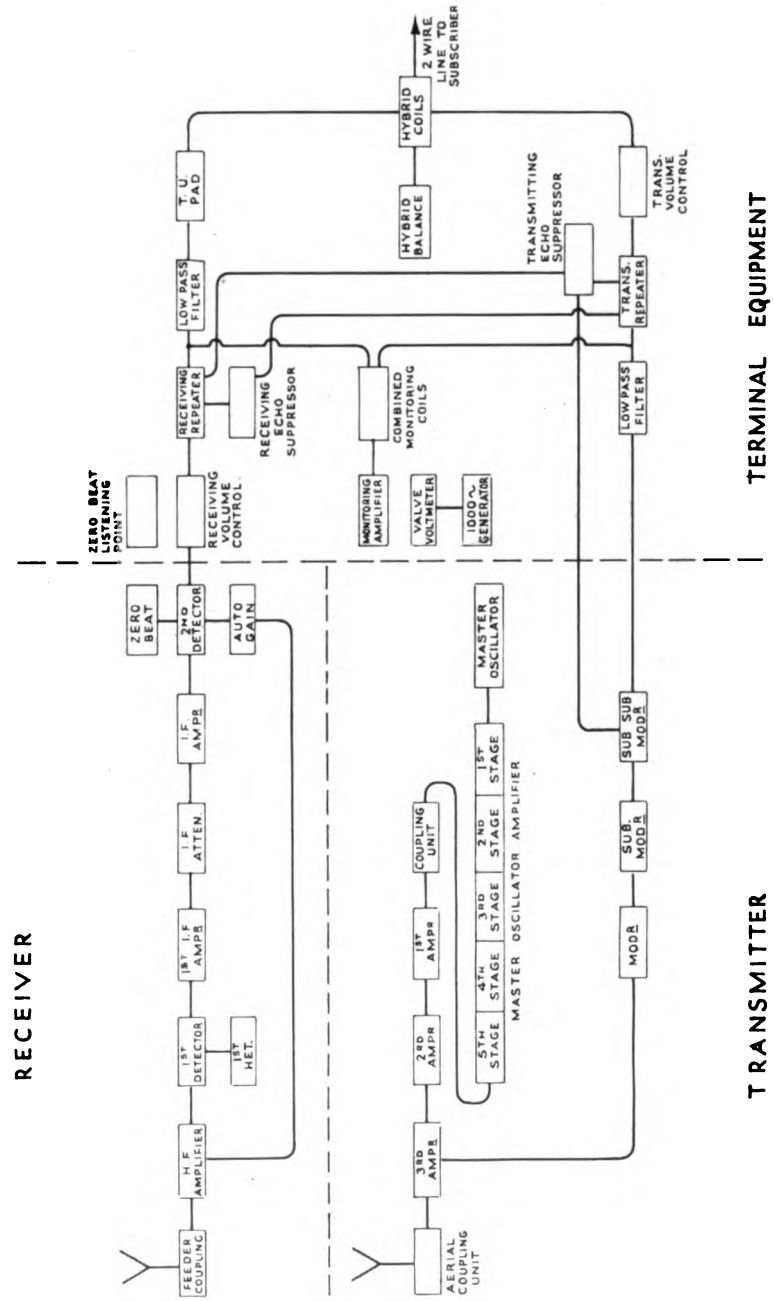

FIG. 3.

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All the power supplies for both units are obtained from duplicate composite motor generator sets situated in a small locker on the deck below. These machines are mounted on similar floors to the receiver units to prevent vibration and noise being transmitted to the passenger accommodation.

The short wave receiver, which is mounted along the forward bulkhead is complete with its own switchboard and testing instruments. It has a wavelength

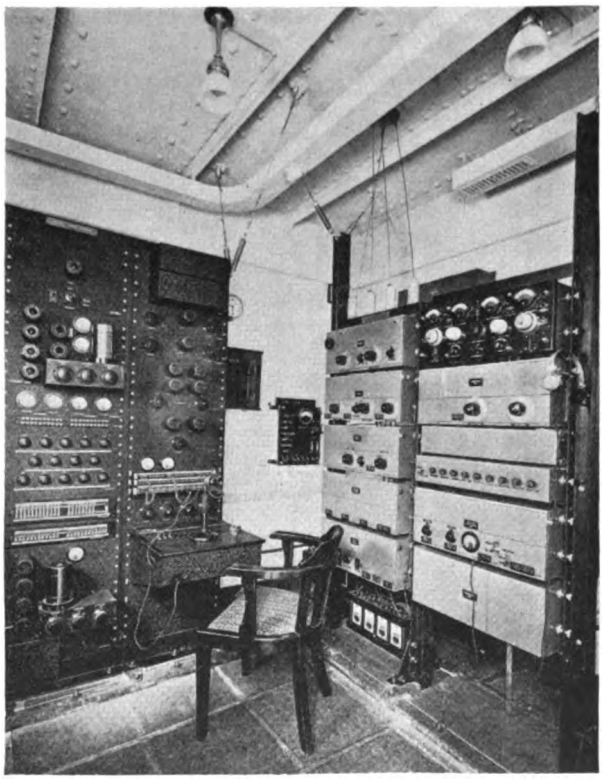

FIG. 4.

range of 14 to 100 metres and is a combination of high frequency amplification followed by intermediate frequency amplification on the superheterodyne principle.

Four stages of transformer coupled screened grid high frequency amplification are available before changing frequency and one of these stages is fitted with optional switches.

The local oscillator for frequency changing is rubber insulated from the adjacent units and frame to eliminate vibration and the power for this valve is drawn from

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low tension and high tension batteries in order to avoid possibilities of frequency variation due to variation of the voltage from the ship's mains.

After changing the frequency to 166 kilocycles (approximately 1,800 metres), a further five stages of filter coupled amplification are available, two of these stages being fitted with optional switching. An attenuator unit to operate on this frequency is also incorporated.

A zero beat oscillator is fitted to assist the operator in setting the intermediate frequency to the middle of the band pass of the intermediate frequency stages, the total band width of these stages being approximately 7,000 cycles.

The detector stage of the intermediate amplifier has a further circuit incorporated with it to provide automatic gain control for the high frequency stages, this varies the grid bias on the high frequency valves in accordance with the strength of the incoming signal and compensates for any variation in signal strength due to fading.

Monitoring System.

The terminal unit containing all the audio frequency stages and monitoring operator's equipment, is mounted along the port bulkhead and is complete with its own measuring and testing instruments.

From the output of a radio receiver the incoming speech is passed through the receiving repeater where the strength is adjusted to a level suitable for the subscriber, a valve voltmeter being incorporated for checking this level.

The subscriber's speech is passed through the transmitting repeater and adjusted for level before being passed on to the modulator panel in the transmitting room, a second valve voltmeter being incorporated to indicate level.

The voice operated carrier control unit is connected in parallel with the output of the transmitting repeater and is provided with its own gain controls and adjustment for delay in switching off the carrier, a relay being incorporated for cutting off the subscriber's receiver while the subscriber is speaking.

A somewhat similar unit is connected in parallel with the receiving repeater to act as an echo suppressor when changing from four wire to two wire working. This change is carried out through hybrid coils and a balancing network to enable the radio telephone installation to be plugged through to any of the telephones connected to the manual or automatic exchanges on board.

A 1,000 cycle valve oscillator is also incorporated in the terminal unit and can be used to modulate the transmitter instead of speech when lining up the circuit. It can also be keyed to enable the operator to telegraph service instructions if desired.

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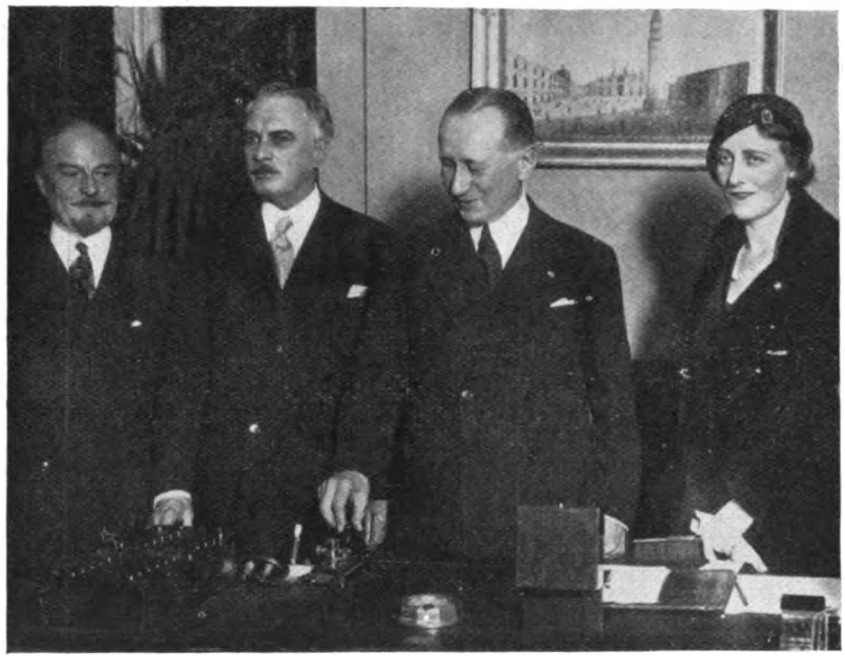
MARCONI NEWS AND NOTES

MARCHESE MARCONI ILLUMINATES STATUE AT A DISTANCE OF 6,000 MILES.



H.E. Marchese Marconi pressing a key in Rome to illuminate the statue of Christ in Rio de Janeiro. Also in the photograph are Marchesa Marconi, H.E. Alceeia def Pecanha, the Brazilian Ambassador in Rome, and (extreme left), Marchese Solari.

HIS EXCELLENCY MARCHESE MARCONI contributed in unique fashion to the celebrations in honour of the anniversary of the discovery of America at Rio de Janeiro on October 12th, when, by sending a wireless signal from Rome, he switched on special floodlights to illuminate the newly erected statue of Christ the Redeemer on the top of the Corcovado Mountain.

The Corcovado Mountain is one of the main features of the landscape of Rio de Janeiro and the sudden illumination of the statue at its summit, just as dusk was falling and 15 minutes before the street lamps were lit in the City, by means of the wireless signal from nearly 6,000 miles away, provided an impressive and awe-inspiring spectacle. The statue stands 130 feet in height, and, with its arms spread in a gesture of benison, overlooks the entire city and the famous harbour.

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The wireless signal transmitted by Marchese Marconi consisted of a Morse dash. His Excellency pressed a Morse key in the Marconi Office in Rome and from there the signal was conveyed by landline to the Italian wireless telegraph station at Coltano—about 150 miles from Rome, near Leghorn—which some years ago was christened "Guglielmo Marconi" in honour of the illustrious inventor. The wireless signal thus despatched from Rome was intercepted by the Marconi Beam receiver at the Brazilian Wireless Telegraph Company's station near Rio de Janeiro and thence transmitted over a telephone landline to the base of the Corcovado Monument, where an automatic switching device for controlling the illumination of the monument had been constructed.

The demonstration was similar in principle to that which took place in March, 1930—described in THE MARCONI REVIEW, No. 19—when Marchese Marconi sent a wireless signal from his yacht at Genoa which switched on the lighting in Sydney City Hall at the opening of the Electrical Exhibition in Sydney, New South Wales.

Faraday Centenary.

LONDON paid high tribute to science and engineering during September, when the centenary meeting of the British Association, the centenary celebrations in honour of Michael Faraday, and the Shipping, Engineering and Machinery Exhibition were held in the Metropolis.

Leaders in every branch of scientific thought gathered to make their contribution to the ceremonies and discussions, and at a special Faraday commemorative meeting tributes to the genius of Faraday were paid by, among others, the Rt. Hon. Ramsay MacDonald, Prime Minister, His Excellency Marchese Marconi, Lord Rutherford, Lord Eustace Percy, and General Smuts, President of the British Association.

A special feature of the Faraday Centenary Celebrations was the Faraday Exhibition at the Albert Hall, which demonstrated many of the principal scientific and engineering achievements based upon Faraday's electro-magnetic discoveries, and which attracted many thousands of visitors.

Historical Marconi Exhibits.

The far-reaching effect of Faraday's discoveries was nowhere more strikingly shown than in the exhibits contributed to this Exhibition by the Marconi Company. Though limited in number owing to the space available, they formed one of the most interesting collections of historical wireless apparatus ever seen at an exhibition.

They included replicas of apparatus used by Marchese Marconi in his earliest experiments at Bologna in Italy in 1895, and original apparatus used by him when he first came to England and gave demonstrations to the General Post Office and the Admiralty in London and on Salisbury Plain. There was a coherer

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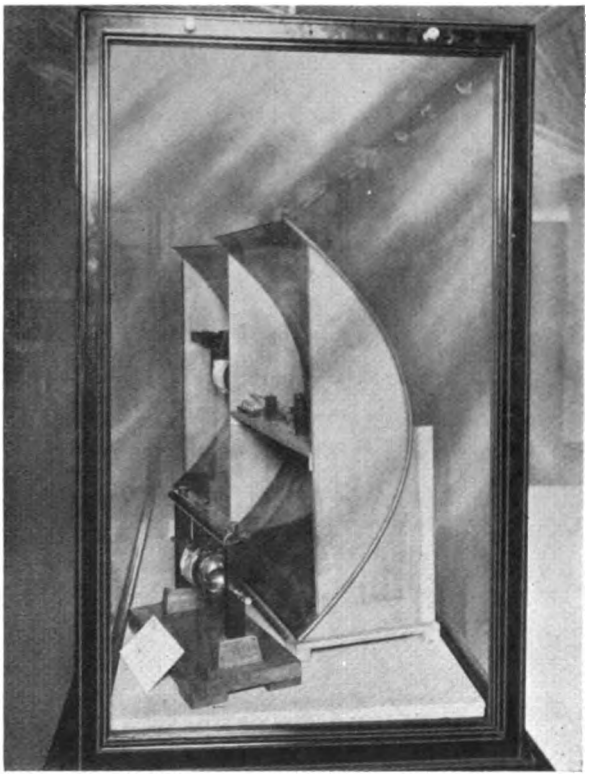
receiver, and early Bellini-Tosi apparatus, consisting of a direction finding receiver and a directional transmitter, of 1907, the one being the forerunner of the direction finder now so largely used on board ship, and the other of the equi-signal beacon which is now being developed for aircraft navigation.

The display also included an arc wireless telephone of 1910, and a series of microphones for wireless telephony illustrating the development of this instrument from the time of the Marzi microphone of 1910 up to the latest Marconi-Reisz type now used in practically all broadcasting stations.



At the Faraday Exhibition: A Righi Oscillator; and replicas of transmitter and receiver with parabolic reflectors as used by Marchese Marconi for communication with ultra-short waves over a distance of 1¾ miles on Salisbury Plain in 1896.

One of the most complete historical collections of valves ever shown at any exhibition provided such contrasts as the experimental two-electrode valves made by Sir Ambrose Fleming from 1904 to 1908, and the giant 100-kilowatt valve of to-day which is used in the largest modern broadcasting stations.

Above the exhibit was suspended one of the kites used by Marchese Marconi in the first trans-Atlantic experiments between Poldhu and Signal Hill in Newfoundland, in December, 1901, which first demonstrated the possibility of world-wide wireless telegraph communication.

Owing to the limitations of space the number of Marconi exhibits had to be curtailed and it was not possible to include any modern commercial apparatus. However, the British Broadcasting Corporation had on view a regional transmitter of Marconi manufacture; and the latest type of aircraft transmitter specially designed for fitting in large aeroplanes and airships was shown in another section of the exhibition.

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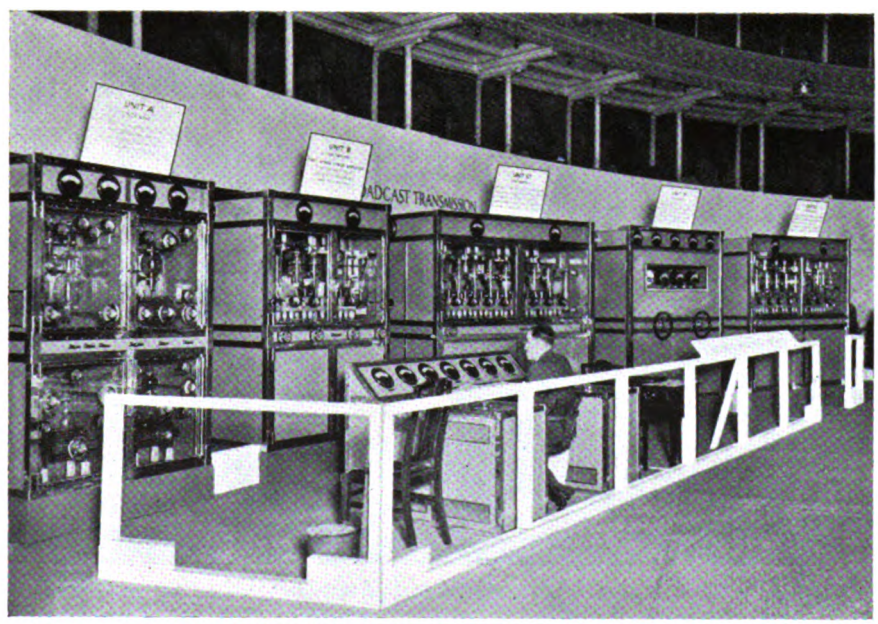
Marconi Equipment Officially Approved.

MANY hundreds of aero-generator windmills developed by the Marconi Company in conjunction with Messrs. Haslam & Newton, of Derby, utilising variable pitched blades operated by means of centrifugal weights are in use in all parts of the world. The British Air Ministry has now notified the Marconi Company that the Marconi-Newton constant speed windmills Types 110, 140, 160 and 180 are approved for use on civil aircraft registered in Great Britain.

Owing to the differing air speeds and other factors involved, the installation of a windmill of any of these types in any particular aircraft registered in Great Britain will be subject to examination in order to ensure its safety on that machine.

The Type 110 windmill has an output up to 100 watts, Type 140 up to 180 watts. Type 160 up to 250 watts, and Type 180 up to 500 watts.

These new models, as approved by the Air Ministry, include important improvements, greater strength and efficiency being obtained by the use of solid blades and a new system of governing, and the general construction being lightened in weight. At the same time head resistance has been reduced.



The latest B.B.C. Regional Transmitter, manufactured at the Marconi Works, Chelmsford.

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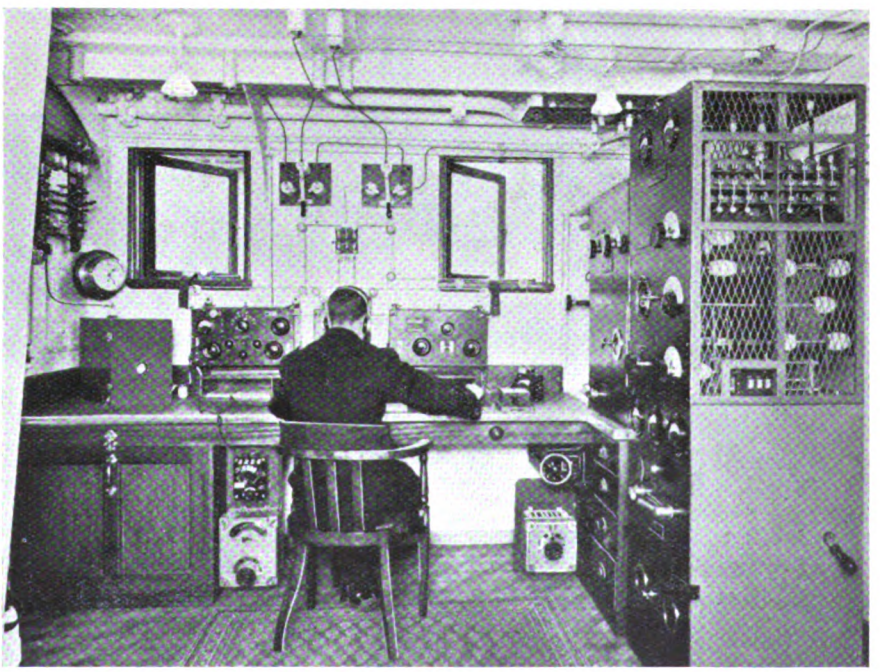
Other Marconi wireless apparatus approved by the Air Ministry for use on civil aircraft registered in Great Britain include the A.D.6h and A.D.6m "all-purpose" 150 watt aircraft telegraph-telephone equipment; A.D.8 long range aircraft telegraph-telephone equipment; A.D.16 aircraft direction finder, Bellini-Tosi system; A.D.18a 350-watt telegraph-telephone transmitter and receiver, the former having an independent "drive" system for maintaining at a constant value the frequency of the radiated wave; A.D.19 150-watt short wave telegraph-telephone transmitter with independent drive, waverange 40-60 metres; A.D.20 short wave receiver waverange 40-60 metres; and A.D.20a short wave receiver, waverange 80-180 metres.

Marconi Marine Telephony.

MODERN Marconi marine equipment was an outstanding feature of this year's Shipping Exhibition at Olympia. The latest installations for wireless telegraphy and telephony, band repeater and music playing equipment, and the Echometer type of Marconi Sounding Device were arranged on a large stand



A modern ship's wireless cabin, showing from left to right: Marconi emergency transmitter, marine receiver (15-20,000 metres) with local oscillator and H.F. amplifier units, and 2 k.w. valve transmitter for long and short wavelengths. The Marconi Direction Finder is fitted in the chart room of this ship.

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on which representative ships' wireless cabins had been built to illustrate in practical fashion the arrangement and fitting of the apparatus.

Guests at the inaugural luncheon of the Exhibition enjoyed a wireless " surprise item," when Lord Wester Wemyss, presiding at the function, received telephone calls from the Captains of the " Empress of Britain " and the " Homeric." Both ships were at the time ploughing their way eastward on the Atlantic, and their Captains were able to voice good wishes to the exhibition through the medium of their Marconi long-distance telephone equipment and the Post Office ship to shore telephone service. The conversations were extremely clear, and were reproduced on loud speakers so that they could be heard by all the guests at the luncheon.

An additional happy significance was given to the occasion by the fact that Sir Austen Chamberlain, First Lord of the Admiralty, was also present at the luncheon, and was able to convey over the wireless telephone circuit the greetings of the Royal Navy to the British Mercantile Marine.

Marconi Equipment for P. & O. Liners.

THE four new liners of the Peninsular and Oriental Steam Navigation Company, " Strathnaver," " Strathaird," " Corfu " and " Carthage," are each to carry the latest type of Marconi marine wireless telegraph apparatus, comprising 2-kilowatt transmitters for long, medium and short wavelengths, and receivers covering the whole commercial waverange, with additional units for strengthening weak signals and reducing interference. To assist the navigators, the Marconi Direction Finder with the fixed frame aerial is installed, the direction finding instrument being fitted in the wireless cabin. The liners carry all other safety wireless apparatus, including an emergency set working from an independent source of power, and lifeboat sets.

The " Corfu " and " Carthage " are supplied with a special type of Marconi Band Repeater consisting of a cabinet containing a double turn-table for gramophone records, an amplifier and a motor generator. Two deck loud speakers are supplied for use when and where they are required, and two other loud speakers, mounted in polished wooden cabinets, are for internal use in the ship. All the loud speakers are fitted with flexible cable and sockets, and have local volume control units to enable them to be switched on or off and the volume to be regulated to suit local requirements.

Marconi Sounding Device.

IN addition to this wireless equipment the " Strathnaver " and the " Strathaird " are fitted with the latest type of Marconi Sounding Device—the Echometer, built on the famous Langevin-Chilowsky system—which gives instantaneously, and without the use of the ship's dynamo, the depth of water immediately under the ship.

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This instrument is silent in operation and can be switched on by the Officer on watch and left running as long as it is required without causing any disturbance to the passengers or crew.

This silent operation is unique among sounding devices, and is due to the fact that the waves transmitted through the water are produced by a small transmitter at supersonic frequency. They are imparted to the water by the projector, which consists of a quartz crystal between two thick steel plates, in the bottom of the ship. The outer of these plates, being made to vibrate by the action of the electrical charge on the crystal, imparts a wave motion to the water, directed towards the sea bed. The only power required for this operation is a 4-volt accumulator. There is no hammer, electric motor or other running machinery, and the same small hull fitting acts as both transmitter and receiver.

A ship's officer "taking soundings" with the Marconi Echometer.

Continuous soundings can be taken, with many readings a minute, and navigators have appreciated the value of operating this device simultaneously with the wireless direction finder. The result is an absolutely correct check of the ship's position, giving true compass bearings from one or more points of land and the depth of water and the consistency of the sea bed under the ship.

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THE MARCONI REVIEW

November-December, 1931

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THE MARCONI REVIEW

No. 33. *Nov.-Dec., 1931.*

Technical Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. RICHARDS.

FEEDER ADJUSTMENTS FOR SHORT WAVE VERTICAL AERIALS

The following notes are written to assist those who are concerned with the erection of omni-vertical aerials and the subsequent connection to feeder lines. It is hoped at a later date to give further notes in connection with beam aerials and feeders generally.

The present problem is one of matching the impedance at the base of an aerial to the natural or surge impedance of a particular form of feeder, the Marconi Concentric type.

AS a preliminary it will be useful to study an aerial with reference to equivalent load resistance.

If Fig. 1 represents a vertical length of wire, let us say slightly less than ten metres long with its lower tip about six feet above ground, it may be taken to indicate a 20 metre half wave vertical aerial which under suitable influence would oscillate in such a manner that the current and voltage distributions are as per the dotted and thin line curves. In order to maintain any particular intensity of radiation it is necessary to feed it with H.F. current such that the current multiplied by the potential at the point of feeding equals power radiated. Since a resistance can always be found such that $R \times I^2 = I \times E =$ power, it is convenient to define the radiating property of an aerial in terms of a resistance, and it is usual to define the radiation resistance of a half wave aerial such that :—

$$R \text{ (radiation)} \times I^2_{max.} = \text{power radiated.}$$

Where " I " is the maximum R.M.S. current, i.e., the R.M.S. current at the centre of the aerial. This resistance equals the equivalent load resistance of the aerial were it possible to feed it at its geometric centre ; *it is thus a fictitious value* but is very useful as affording some idea of the relative radiating properties of various aerials. The rough figure for a half wave aerial varies between 120 and 80 ohms, the latter being for an aerial well above ground while the former is for an aerial close to the ground where absorption is great and the useful radiation perhaps not more than 20 per cent.

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The other value of resistance, and the one that now concerns us more closely is such that—

$$E^2 \text{ max.}/R = \text{power radiated}$$

where $E_{max.}$ is the maximum R.M.S. voltage between earth and the lower tip of the half wave element. (To be logical this might equally well be written $R \times I^2_{min.}$ where $I_{min.}$ is the minimum R.M.S. current, which can conveniently be regarded as the space current about the tip of the aerial). Let us call the equivalent load of the aerial when fed in this way " R base " : this will vary with the overall height of the aerial measured in wavelengths and for the half wave element with lower tip about six feet above ground may be of the order of 2,000 ohms. If the half wave element is replaced by a higher one the value drops and, as the height increases, tends towards a constant figure of perhaps 600 ohms. This " R base " might be called the " aerial base resistance " and is the value that interests us at present since it indicates the nature of our problem, viz., how to match a base resistance varying between 2,000 and 600 ohms to a feeder whose correct termination should be equivalent to about 75 ohms.

Half Wave Vertical Aerial.

Taking first the case of a simple half wave aerial, the practice is to erect the element with its base anchored and insulated about 6 feet above ground level, and from the base end to run a horizontal tail to the aerial transformer box, the tail being usually about one-eighth wavelength long ; thus the aerial together with its tail, tuning coil, and lead from box to ground totals approximately three-quarters of a wavelength and enters the ground at a point of no potential. In Fig. 2, Sketch (A) indicates the actual run of the aerial with its coil and earth leads ; while Sketch (B) indicates the equivalent plain straight wire.

Since the lower quarter wavelength is composed mainly of a low horizontal wire and a coil it will be regarded as non-radiating and may therefore be replaced, figuratively and without violating principles, by a closed circuit as per Sketch (C) of Fig. 2, in which " L2 " represents the equivalent inductance of the quarter wave element and " C2 " its *effective* capacity to earth. This combination will oscillate to the natural frequency of the vertical half wave aerial because while " L2 " is only half the inductance of the latter, " C2 " is twice the effective capacity, since in one case the capacity is between the upper and lower sections of the half wave element while in the other case the capacity is between one such section and earth, or neutral.

We have now an open half wave element coupled to a closed circuit in tune with it ; owing to the direct coupling the load due to radiation will be thrown into the closed circuit and in fact may be represented by a series resistance " R " equal to the radiation resistance of the half wave aerial. But, from the theory of tuned

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circuits, we know that, at tune point, the closed circuit is equivalent to a pure resistance—

$$(\omega L_2)^2/R$$

This is the aerial base resistance and therefore the equation gives the relation between the aerial base resistance and the aerial radiation resistance : if we prefer the equation in terms of L, the inductance of the half wave aerial, then since L_2 equals half L the base resistance equals :—

$$(\omega L)^2/4R$$

Next, let us consider how to couple up this base circuit to the feeder that is energising it, in other words, how to transform the base resistance into R_O, the surge impedance of the feeder. Obviously the thing to do is to tap the feeder some way up the base inductance, but unfortunately this does not yield the simple transformer effect desired because of the two circuits which comprise the transformer only one, the aerial circuit, is tuned ; the other consists of perhaps one or more turns of coil unbalanced by any capacity, i.e., it is untuned. Thus, though the ratio of aerial coil turns to feeder tap turns may be such as would give the correct ratio between R_O and R_B, the feeder tap is an unbalanced inductance and will make the load thrown on to the feeder quite inductive, whereas it must be purely resistive. The problem is how to make the feeder load non-inductive. For simplicity let us, as in Fig. 3, indicate the feeder tap as a separate coil or loop with a coupling of mutual inductance to the aerial base coil, then adopting the symbols of Fig. 3 and assuming the far end of the feeder to be connected to a source of high frequency power, let us trace the coupling reactions.

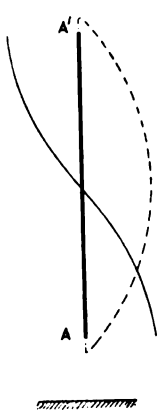

FIG. 1.

Inductively Coupled Circuits.

Assuming the aerial base circuit to be in tune with the aerial it is equivalent to a pure resistance that we have termed " R base " ; again we have the feeder terminating in a simple coil whose inductance is not neutralised. After coupling one to the other by an appropriate number of turns we might insert a series capacity to balance the feeder coil inductance, see (B) of Fig. 3, but such a procedure is not very practical and so we must devise some other means.

We know from the theory of tuned circuits that for a given value of inductance, capacity and resistance, the characteristics of the circuit vary as the frequency ; thus as the frequency of the applied E.M.F. approaches, coincides with and exceeds the natural frequency of the circuit, so the equivalent resistance (as measured between A and E of Fig. 3) rises rapidly, reaches a maximum and falls again towards some approximately constant value. Also for frequencies lower than the natural

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frequency of the circuit the reactance is capacitative, while for frequencies higher than natural frequency the reactance is inductive.

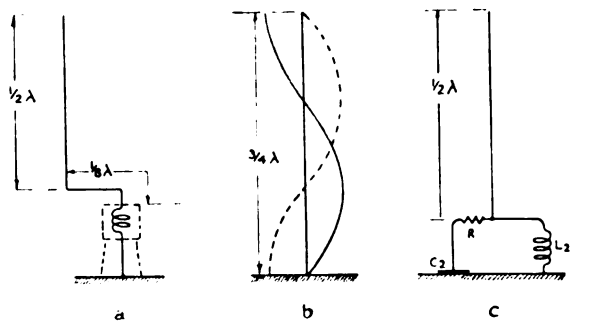

FIG. 2.

To understand the coupling reactions, between the feeder loop and the aerial base circuit, let us examine the characteristics of the latter. In Fig. 4 the curve (1) indicates inductive reaction, curve (2) indicates capacitative reaction, curve (3) indicates the combined result of these two components, while curve (4) gives roughly the resistance component. When the frequency is " n," the natural frequency of the aerial, the two reactions are equal and opposite and the circuit exhibits only a pure resistive effect, but on either side of " n " there is a reactance component which is capacitative or inductive according as the frequency is lower or higher than " n." If, however, the circuit is detuned by increasing either the capacity or the inductance it is apparent from Figs. 5(A) and 5(B) that *the reaction at* " n " *is inductive.* Leaving it inductive, we will trace the relations between feeder-loop and circuit. An E.M.F. from the feeder coil induces a current in the circuit which has a resistive component in quadrature with the E.M.F., and also, since the circuit is inductive, a reactance component which must be in quadrature with the resistance component, and therefore one hundred and eighty degrees ahead of the E.M.F.

Both components couple back on to the feeder loop, but for the moment that which interests us is the reactive component, which induces a current in quadrature with itself and therefore 180° plus 90° ahead of the feeder E.M.F.

To sum up, the total effect of the inductive reactance in the circuit when coupled back on to the feeder loop has been to induce a current in the loop 270° ahead of the feeder E.M.F. ; but this is equivalent to a current leading by 90°, in other words, to a capacity current in the feeder loop. The effect, then, of detuning the aerial base circuit to a lower frequency is to throw back into the feeder loop a certain amount of capacity reaction. By careful adjustment it is possible to take advantage of this effect and balance out the induction of the loop itself, leaving the resistance

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component as the nett result of the coupling. So far little has been said about this resistance component, which, after all, is the main objective, but it must be already apparent that when we change the tune of the aerial base circuit the resistance curve alters appreciably from curve (4) in Fig. 3(A) and flattens out ; it is unnecessary to go more deeply into the analysis since it is clear that the feeder tap, i.e., the amount of coupling, now appropriate for the termination of a Marconi Concentric Feeder, differs appreciably from the tap that would have been suitable had the aerial base circuit been in tune.

The simplest method of detuning is to increase the aerial coil turns, and this explains why the turns in the aerial coil are generally more than called for if it were a simple case of tuning. When the available aerial turns appear to be too few, another method is to detune with additional capacity across the aerial coil, by means

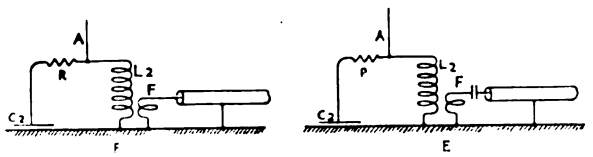

FIG. 3.

of a length of feeder tube as indicated in Fig. 4, but this is a method seldom adopted, although it appears to be suitable for all receiving aerials. Unless on low power the device may not be suitable for transmitting aerials because of the possibility of high potentials and the risk of sparking, all the same, under suitable conditions it is helpful.

High Aerials.

We will next take the case of vertical aerials that are higher than half a wavelength, more particularly those built on the " Uniform " principle ; before, however, examining the practical aspect of appropriate feeder adjustments it is necessary to understand the precise difference between a low aerial and one that may extend to a height of two wavelengths, or even more. To obtain the full benefits of height, radiation should not vary in either sign or intensity along the length of the aerial, at any rate to well within a quarter wave of the ground ; in other words, the sign of aerial current should be constant, while its distribution should be practically uniform throughout the effective length of the aerial.

Were it possible to extend the height of an aerial by simply piling up one half wave element on top of another the non-uniform or sine form of current distribution would be perfectly satisfactory, but after considerable experience it has been proved that loss of efficiency follows even the most careful systems of maintaining uni-phase sine current distribution. It is true that harmonic aerials are sometimes employed, but, owing to the natural current distribution of plus and minus signs, this type

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radiates at a high angle and is most inefficient and prone to interference for any but certain special requirements. Thus, while uniform current distribution has no advantages over sine distribution for low aerials, that is, the simple half wave element would be as efficient as a half wavelength high uniform-current aerial, were such possible, yet when conditions call for the use of high aerials the Marconi uniform system is far and away the best method devised.

Advantages of High Aerials.

Were it only a matter of avoiding ground losses it would be quite practical to raise a complete half wave element well above ground level, connecting it through some known form of feeder, and thus ensure almost 100 per cent. effective radiation. But while this is certainly one factor, there are two other important factors that bear on the quality of transmission or reception. The first is that as the overall height

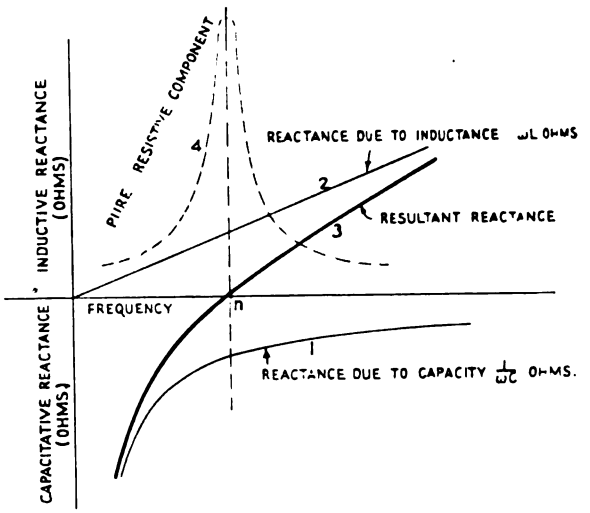

FIG. 4.

in wavelength measurement is increased, so the angle of total emission in the vertical plane becomes narrower and the main stream of energy more concentrated, thus not only is there gain of magnification in the required direction, but the transmission or reception in respect of unwanted directions becomes highly attenuated: this advantage amounts to " signal selectivity " and is very important when it has relation to unwanted out-of-phase signals of the same frequency as the message, a situation with which no known form of receiver can cope.

The second factor applies only to the Marconi Uniform Aerial. This design lends itself to a control of the upward tilt of the direction in which the main stream

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of energy leaves or enters the aerial, a facility that has proved to be of very practical advantage on many services.

It might be argued still that for a given available mast height it is better to sling up a half wave element and thus raise the centre of the aerial by the maximum possible amount, but apart from the supreme advantage of selectivity gained by actually extending the height of the aerial, a moment's consideration will disclose that in any case the upward tilt and the magnification more than compensate for any difference in average height.

On the other hand, it should not be overlooked that, even in those rare cases where the cost of high masts is not a prime consideration, it is not practical to extend an aerial by more than two wavelengths because of reflection effects, hence, where more than the limiting height is available, the practice is to design an aerial

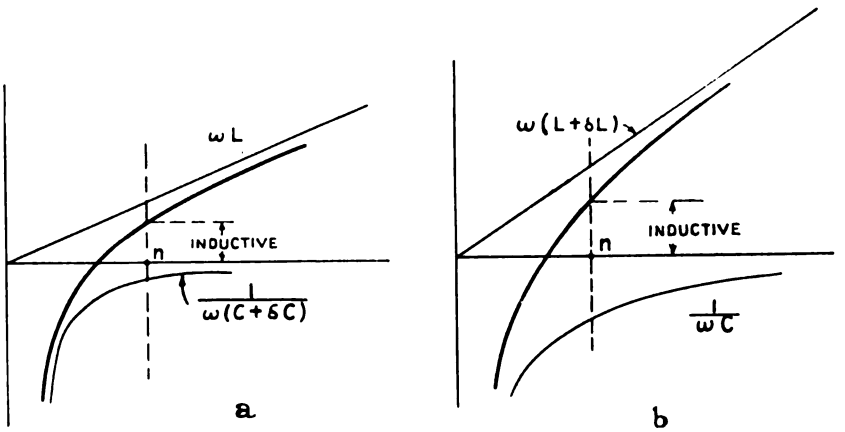

FIG. 5.

extending to one-and-a-half or two wavelengths, and to raise the complete unit above ground, connecting it to the ground feeder through a length of Marconi non-radiating aerial feeder.

Adjustment of High Aerial Feeders.

Purely from the point of view of transformer adjustments, the effect of height and of a uniform build of aerial is that, with the consequent increase of radiation resistance, there is a corresponding decrease of base resistance. (It should be fairly obvious that this is so, since if we flatten out the current there must also be a flattening out of potential; hence the potential between the lower tip of the aerial and earth has diminished, hence also a diminution in the "base resistance.")

The value now tends towards 600 ohms as compared with the 2,000 or 2,500 ohms value for the equivalent base resistance of a half wave aerial. At first sight this

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condition may appear easier to handle, because it would seem a simpler proposition to transform down to 75 ohms from a 600 ohms circuit than from a 2,000 ohms circuit, but unfortunately the actual transformation is more difficult. This is explained by the flattening of reaction, in fact reaction is being swamped by an increase in the radiation resistance and it has become very difficult to determine when the aerial base coil is in tune, let alone any subsequent question of adjustments. Thus, if there is difficulty in tuning, there is still more difficulty in detuning sufficiently to exhibit any marked inductive reaction, and we might almost pile up turns in the aerial coil indefinitely and still not have enough reaction to cancel out the feeder loop inductance.

In this case there are, roughly, four courses open :—

(A) A series of fortuitous factors may lead to a satisfactory balance between aerial turns and feeder loop with very little trouble.

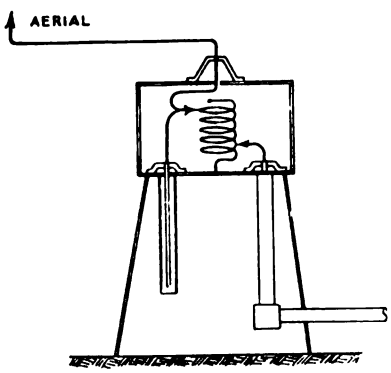

FIG. 6.

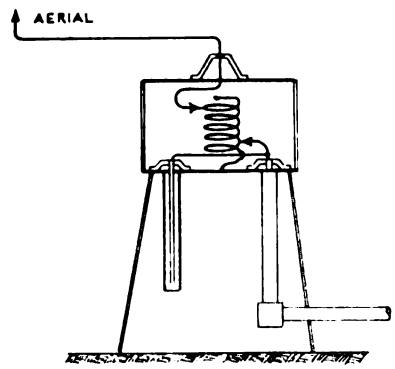

FIG. 7.

(B) The method indicated by Fig. 6 may sometimes be employed with advantage on receiver aerials, and also on low power transmitter aerials, since with high aerials the voltages will be fairly low.

(C) The length of the aerial tail may be varied, with the hope of finding a fairly reactive point to connect on to the aerial coil, thus sharpening up the effect of varying turns in the latter.

(D) Finally advantage may be taken of the following relationship between inductance and resistance in parallel, and inductance and resistance in series. If at any particular frequency the reactance of an inductance L_0 measures R_0 in ohms, then L_0 in parallel with a resistance of R_0 ohms is equivalent to half L_0 in series with half R_0. It follows that if the feeder is loaded up to half R_0, by an appropriate tap whose inductive reaction is half L_0 then the conditions in the feeder terminal loop give half R_0 in series with

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half L_O; but this is equivalent to R_O in parallel with L_O. Hence if L_O is neutralised by means of a parallel capacity, we are left with a pure resistance load R_O on the feeder. Remembering that one-eighth wavelength of feeder has a capacity reaction equivalent to R_O it will be realised that this method is a practical one, since a length of feeder can be inserted as shown in Fig. 7.

It will be appreciated that in principle the method calls for no detuning, since we are no longer concerned with neutralising the feeder loop by reactive coupling effects but are simply concerned with throwing into the feeder a load equivalent to half R_O. This is a fairly simple proposition calling for a tuned aerial circuit and a weak coupling.

Objection may be raised on the grounds that it is unlikely we shall obtain a tap whose inductive reaction is half L_O when the coupling effect of the tap just gives half R_O, but, as a matter of experience, under tune conditions and within the rather wide limits of our approximations, load coupling and inductive reaction have a certain fortunate parity.

In practice the method is adopted when it becomes apparent that to get anywhere near the desired adjustment the feeder tap turns are mounting unduly. It is largely a matter of compromise, which means that it is seldom expedient to insert the generally fairly long length of feeder (one-eight wavelength) whose capacity reaction equals 75 ohms, but even a limited application of the principle may give the desired results.

In conclusion the following notes are given as of general interest in connection with aerials.

There are three simple formulæ relating to closed tuned circuits, in which the capacity and inductance is concentrated into two separate elements, that are applicable to an open *tuned* circuit or aerial, in which capacity and inductance is distributed and generally measured as so much per centimetre run of aerial wire. Since the fact of distribution calls for some readjustment of our perspective when defining the constants, it may help if we briefly review the definitions before applying the formulæ.

Effective Aerial Capacity.

From the potential distribution shown in Fig. 1, it is clear that the charge oscillates from tip to tip and therefore the capacity is that of one-half of the aerial with respect to the other, that is, the capacity to space of one-half is in series with the capacity to space of the other half. But two equal capacities in series are equivalent to one-half of the single capacity, thus the effective capacity is one-half the capacity of half the aerial. If C signifies effective capacity and C^1 the total or static capacity, then $C = \frac{1}{4}C^1$.

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Owing to the sine form current and voltage distribution we should multiply C by $\frac{2}{\pi}$, but the form factor will cancel out of the equations and therefore does not appear below.

Base Voltage.

It is obvious that the maximum voltage of an aerial is across the ends, therefore the voltage of one end to earth is half the maximum voltage.

Surge Impedance.

The surge impedance of a conducting system may be measured by the formula $Z_0 = \sqrt{\frac{L}{C}}$ where L and C are the distributed inductance and capacity per unit length of conductor. In the case of an aerial the conducting system may be regarded as a single wire of finite length and the ratio of total inductance to total capacity is the same as the ratio of inductance per unit length to capacity per unit length.

Bearing the above relationship in mind we can apply the three well-known formulæ :—

$$\text{Power} = R I^2 = V^2/R \quad .. \quad .. \quad .. \quad .. \quad (1)$$

$$\text{Power} = \tfrac{1}{2} L I^2 = \tfrac{1}{2} C V^2 \quad .. \quad .. \quad .. \quad .. \quad (2)$$

$$\text{Angular Velocity } W = 1/\sqrt{LC} \quad .. \quad .. \quad .. \quad (3)$$

where I may be taken as maximum R.M.S. current, V the maximum R.M.S. voltage, L total inductance and C the effective capacity.

When applied to an aerial we write :—

$$R \text{ radiation} \times I^2 = V^2/4 \times R \text{ base}$$

$$LI^2 = C^1V^2/4$$

$$\omega^2 = 4/LC^1$$

from which we can obtain

$$R \text{ base} = \omega^2L^2/4R \text{ radiation.}$$

Obviously as we increase the height of the aerial R_R increases and therefore R_B decreases. (Note that L remains constant, since the frequency is constant and therefore the effective inductance is still that of the half wave element.) In the limit R_R equals R_B and we have

$$R^2 = \omega^2L^2/4 = L/C^1$$

therefore $R = \sqrt{L/C^1}$. But this is the surge impedance of the aerial ; hence as we extend the height of the aerial, the terminal resistance tends to coincide in value with the radiation resistance and both tend to coincide with the surge impedance of the aerial wire.

The surge impedance of No. 14 wire about 12 metres above earth is 600 ohms and this may be regarded as a rough general figure for the surge impedance of an aerial, hence in the limit a high uniform aerial may be regarded as a feeder with radiation acting as distributed resistance and possessing surge or terminal impedance of 600 ohms value.

N. WELLS.

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A GRAPHICAL SYNTHESIS OF AERIAL ARRAYS

The following article describes a simple method of calculating graphically the polar diagrams, both in a vertical and horizontal plane, of any array of spaced aerials.

The basis of the method is the combination of two diagrams, both of which are easily constructed from a knowledge of the array constants.

THE approximate theoretical diagram of spaced aerial systems can most easily be worked out by direct mathematical means, such for instance by application of the simple formulæ developed originally by E. Green, but such methods usually assume an infinite number of aerials for convenience, a condition never met with in practice, and the simple mathematical treatment is not suited to all cases.

A graphical method of building up such diagrams although involving—initially—the careful plotting of a few " standard " diagrams, gives accurate results, enables one to analyse rapidly any complicated array system, and the method is most useful as illustrating the way in which the final interference pattern is gradually evolved. For the production of " beam " effects by modern aerial systems is not a true reflection problem but is brought about by the interference of the fields from a group of radiating systems having definite positions relative to one another in space.

The graphical method to be described is based on the principle that the complete diagram of any spaced system of unit radiators having the same characteristic, is, the product of what may be called the spacing diagram by the unit diagram. The spacing diagram is that given by two spaced point sources of radiation (circle diagram) and its shape will depend upon their distance apart in terms of the wavelength, and phase of the point sources. The unit diagram on the other hand, is dependent upon the diagram of the sources themselves.

For instance, if the unit sources are frames their diagrams would be figures of eight, if verticals, circles. It is clear that since the unit diagram is a function of the source itself, the position in space is immaterial.

The spacing diagram on the other hand is a function of the interaction of two units and will vary with the phase and position of these units, and as will be shown later its shape is determined by the spacing in terms of the wavelength and phase. With very close spacing, i.e., less than one quarter of a wavelength, there is never very great phase difference between the fields (unless deliberately produced) and hence the polar diagram is nearly circular but as the spacing is increased beyond half a wavelength to many wavelengths, there are positions where the fields cancel, and positions where they add, so that a complex interference pattern is produced. The evolution of such a pattern is shown in Figs. 1, 2, 3 and 4 (shown more accurately in *a*, *b*, *c*, *d*, Fig. 22), which give the polar diagram of two spaced point sources of radiation fed by current in phase, at spacings of $\frac{1}{4}$, $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2 wavelengths. Observe how the " tails " are sharpened up and more produced as the spacing is increased.

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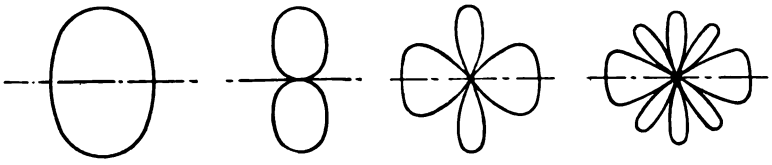
Had the phases of current been 180° apart, the diagrams are changed as shown in Figs. 5, 6 and 7. For wavelengths less than $\frac{1}{2}\lambda$, the diagram is completely changed with change of phase, but with $\frac{1}{2}\lambda$ and greater spacings, the diagram is reversed, not rotated. With phases other than these, the diagrams will change in shape between the two extreme forms shown, but generally speaking one is not often called upon to consider cases of this nature.

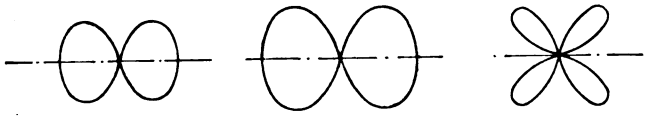


¼ λ FIG. 1. ½ λ FIG. 2. 1 λ FIG. 3. 2 λ FIG. 4.

It is of interest to show how the spacing diagram is evolved. Fig. 8 shows two point sources A and B with current in phase, spaced a distance AB = $n\lambda$° apart in the "*xx*" axis. Thus if AB is half a wavelength spacing the sources are 180° apart. At any angular direction AP, say θ° from the normal to "*xx*," the phase difference between A and B is

$$\Phi^\circ = n\lambda \sin \theta$$

Now the resultant field in any direction AP is the vector sum of the two fields "*a*" and "*b*" whose angular phase difference is seen to be Φ°.



¼λ FIG. 5. ½λ FIG. 6. 1 λ FIG. 7.

If we assume the fields "*a*" and "*b*" to be equal (to unity say) the vector sum is OQ Fig. 9.

$$\text{Now} \quad OQ = 2\ OM \text{ and}$$

$$OM = ON \cos \frac{\Phi}{2}$$

$$\text{Thus} \quad OQ = 2b \cos \frac{\Phi}{2}$$

Had the initial phase of currents in A and B not been zero but some angle Ψ, this must be taken into account and the complete expression becomes :—

$$\text{Resultant field } OQ = \Psi \pm b \cos \frac{\Phi}{2}$$

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The $\pm$ is necessary as with odd phases, the diagrams become lop-sided due to the reversal of phase sense of the interfering fields as one passes through the 90° position.

With anti-phase currents in " *a* " and " *b* " the resultant is the vector difference namely, LN and LN $= 2b \sin \frac{\Phi}{2}$

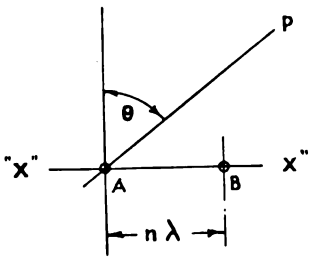

FIG. 8.

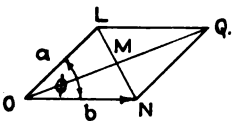

FIG. 9.

An example of misphased currents in two spaced sources is found in the ordinary reflector aerial. Thus consider a single aerial and single reflector spaced one quarter wavelength behind. Their current phase is quadrature and the diagram produced is as shown in Fig. 10 which is seen to be nearly a cardioid. This is the result that would be obtained by two such point sources operating in the above manner and we are not discussing any possible mutual coupling between the sources modifying the diagram. Actually in practice a somewhat greater spacing is found necessary on this account. If one considers a reflector wire spaced three-quarters

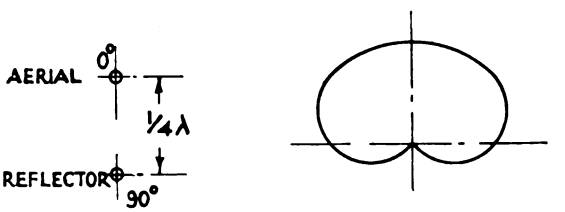

FIG. 10.

of a wavelength behind the aerial, a common setting for the reflectors on the shorter wavelength, the diagram is seen to be quite different. One still gets phase addition forward, and phase opposition behind but the diagram otherwise is quite altered as shown in Fig. 11.

The foregoing may be called " standard " diagrams and they will be used to produce the diagrams of various arrays. For instance consider an array of four aerials each spaced half a wavelength apart, all fed by current in phase, with a similar array acting as a reflector, as shown in Fig. 12, we may visualize each aerial as a unit source of zero phase radiating a circle diagram. Neglecting the reflector

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and considering sections of the array, we may group 1 and 2 together as a pair, and 3 and 4. But if we take each pair these give the elongated figure eight (standard diagram Fig. 2) at right angles to the array line and thus we could replace the four original single units half a wavelength apart, each giving a circle diagram, by two units one wavelength apart each giving the elongated figure eight.

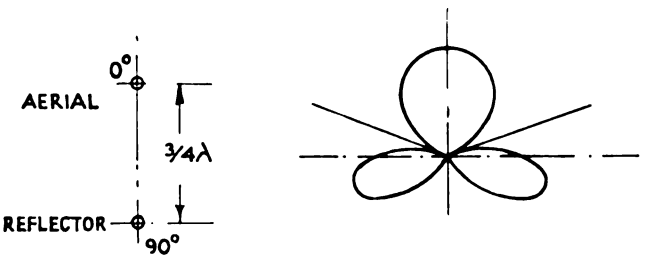
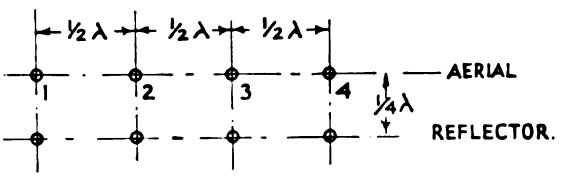


FIG. 11.



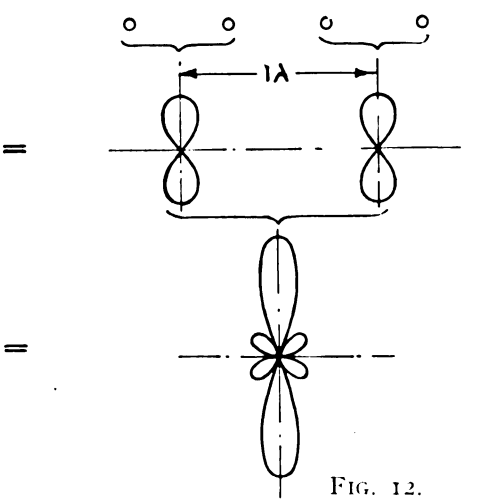


FIG. 12.

Now if we had two circle sources one wavelength apart in phase they would give the standard diagram Fig. 3, by virtue of spacing, but since the sources are not circles, but give the half-wave figure, the total polar diagram is the product of the

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two (namely, standard diagrams Figs. 3 and 2). The result is to give the bi-directional figure as shown in Fig. 12.

If the reflector is now considered, as this can be assumed, separately, to give a similar polar diagram to the aerial array, but with a quadrature phase of current, and to obtain the total diagram it is only necessary to find the product of the resultant diagram of Fig. 12 with the " standard " reflector diagram Fig. 10 if the spacing is

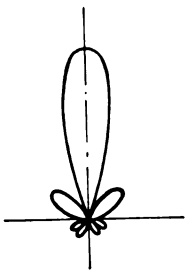

FIG. 13.

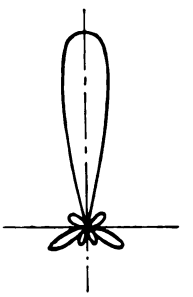

FIG. 14.

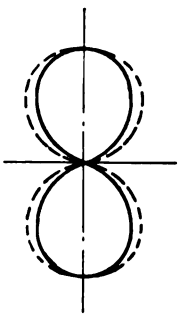

FIG. 15.

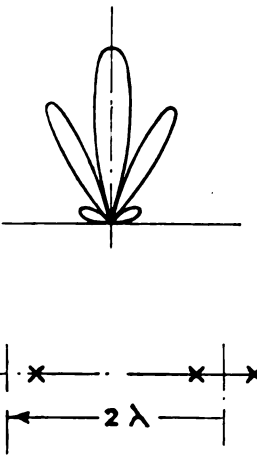

FIG. 16.

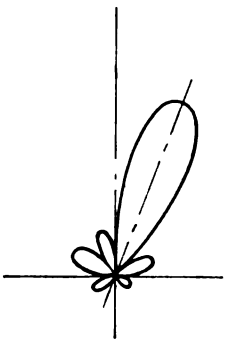

FIG. 17.

one quarter wavelength, and Fig. 11 if three-quarters. The result of each is shown in Figs. 13 and 14 from which we can observe that the former gives a better cut off behind, the latter a better diagram at angles near the array line.

To obtain the diagram of an eight unit array needs but one step from the last array considered, as we have merely to take the product of the 4-array polar diagram and the spacing diagram of two point sources two wavelengths apart (standard diagram Fig. 4). The resultant figure is shown in *h*, Fig. 22.

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An interesting case is the difference between close and wide spacing of aerials in an array. For instance what is the gain of using four elements each spaced $\frac{1}{4}\lambda$ as against two elements spaced $\frac{1}{2}\lambda$. The comparison is shown in Fig. 15, where the dotted curve is the two elements spaced $\frac{1}{2}\lambda$ and the full curve the four spaced $\frac{1}{4}\lambda$, from which it is clear the gain is extremely small from the diagram point of view. Actually in practice there is a gain in putting more elements in the space and this is to make the system more flat-tuned so that it can be used for a band of wavelengths, without serious loss of efficiency. The diagram of four elements spaced $\frac{1}{4}\lambda$ apart is found by multiplying the diagram of two units $\frac{1}{4}\lambda$ apart in phase (standard diagram Fig. 1) with the $\frac{1}{2}\lambda$ diagram.

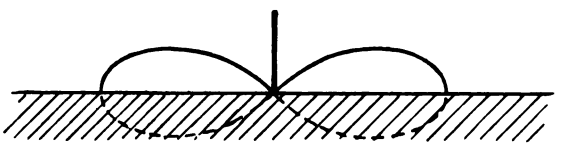

FIG. 18.

By changing phases and spacing a large variety of diagrams can be produced but in general the number of minima and maxima will depend on spacing, in every quadrant one minimum and one tail for every wavelength spacing with one additional maximum (or minimum) depending upon phase. The changing of phase merely alters the relative shape of these tails and their angular position.

If two or three main tails for radiating to stations away from a line normal to the line xx are required we can " split " the diagram in a variety of ways, either by changing the phase of current in each unit, or by using pairs of aerials with wide spacing, an example of the latter being shown in Fig. 16 which gives the diagram of two pairs of elements each half-wave apart spaced two wavelengths.

In practice, to divert a train beam a few degrees, is done by making a small phase shift of each aerial such that the fields add in the desired direction. For instance consider a shift of main beam of 10 degrees with a four element array. This will require a phase shift of 30° per element with half-wave spacing, and the resulting diagram is shown in Fig. 17.

It is now proposed to deal with the zenithal diagram of aerial systems, and in general all aerials are to be considered as made up of elementary radiating pieces of very short length through which passes uniform current.

An elementary length of wire in free space with uniform current radiates a maximum at right angles to its length (proportional to the current passing) and zero in line, and the complete diagram is a cosine considered from a plane normal to the length.

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An aerial is made up of a number of such elementary lengths, the radiation being greatest at those points where the current is greatest and up to a length of wire $l = \frac{\lambda}{2}$, all sections of the aerial assist to produce radiation in the same phase.

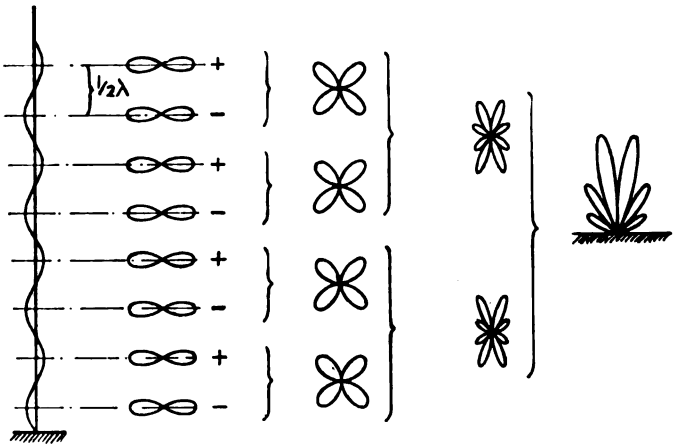

FIG. 19.

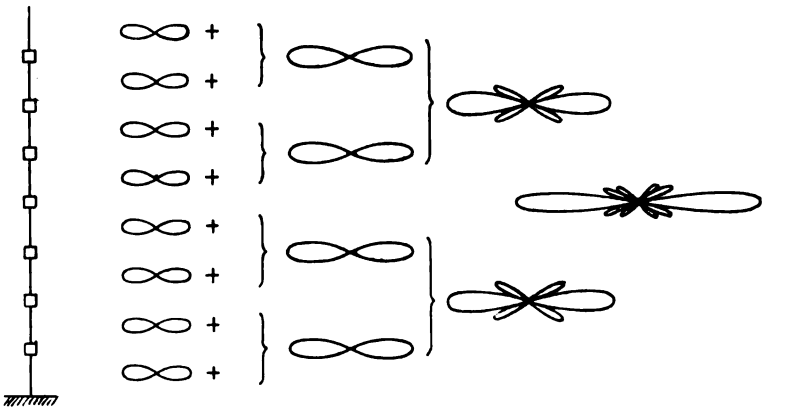

FIG. 20.

Because of the now, non-uniformities of current and the length, the shape of the polar diagram is no longer a cosine but almost a cosine^3, shown in Fig. 18.

If the effect of a conducting earth is considered this cuts off half the diagram and if the earth is a bad conductor more than half will be cut off.

Thus we can consider any aerial whose length is long compared to the wave-length, such as all short wave aerials, as made up of a series of point sources, one

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for every half wavelength of wire, each radiating a cosine^3 diagram with a phase dependent upon the type of aerial used. For instance consider a harmonic aerial of say 4-wavelengths long, as shown in Fig. 19. This may be considered as made up of 8 units spaced $\frac{1}{2}\lambda$ apart, with alternate phase of current in each. Each unit radiates a cos^3 diagram and thus for each pair of half wavelengths of wire, we have the product of a cos^3 diagram with the $\frac{1}{2}\lambda$ out of phase diagram.

FIG. 21.

Each pair can now be combined by the last diagram and standard 1λ in phase diagram and so on and the final figure is as shown in 19 where the image has been omitted as cancelled by earth. Actually the diagram is not strictly correct, as a conducting earth would not hold for the waves used on harmonic aerials, but this can be allowed for by a modification of the original cos^3 diagram, adopting Eckersley's theorem of antiphase images. But where the diagram is giving high angle radiating such as this, the difference is too small to be observed, as the anti-phase image theorem is only correct for angles up to the critical value, which for all waves is low.

If an aerial with phasing units is considered similar grouping is obtained except the first products are obtained with *in phase* diagrams and this entirely changes the final result as is seen by studying Fig. 20. Here the conducting earth does not give a true picture of affairs except for the upper part of the diagram and the diagram of 21 is the result of taking the effect of a bad conducting earth into consideration.

Other interesting cases are the non-radiating Franklin single wire feeders, which can be regarded as series of half wave aerials doubled up into spacings of quarter-wave or less ; and the harmonic aerial and attendant reflector, erected at a shallow angle to the ground to " project a tail " at the required shallow angle, but these will be left for the reader to produce.

A. W. LADNER.

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AN APPLICATION OF THE CIRCLE DIAGRAM TO THE DESIGN OF ATTENUATION AND PHASE EQUALISERS

(PART 1)

It is well known that it is possible in a case of circuits arranged as for either parallel or series resonance to adjust the values of the resistances of the capacity and inductance in such a manner that the total impedance measured across the circuit is real and constant for all frequencies.

This condition is applied in what follows to the design of attenuation and phase correcting networks.

CONSIDER the combination of resistances capacities and inductances shown in Figs. 1A and 1B. The impedance between the points 0 and 2 is at all frequencies equal to R if the inductance L and the condenser C be so chosen that $\sqrt{\frac{L}{C}} = R$. The mathematical proof of this can be quite easily developed, either by the use of orthodox circuit analysis or by the circle diagram as used by Professor Mallet and others. The latter method is followed here as a construction leads to useful extensions of wide application.

Referring to Fig. 1A the total impedance across 0—2 is the vector sum of the two impedances 0—1 and 1—2. Now, to find the impedance of these two sections 0—1 and 1—2 it is necessary to add the admittances of the parallel elements in each section in order to obtain the total admittance, and the impedance of the sections is then found by taking the reciprocal of the total admittance. The two impedances 0—1 and 1—2, are then added vectorially to obtain the total impedance 0—2.

Fig. 2 illustrates the graphical construction by which this can be done. It is essentially a vector diagram of which the point O is the origin. On OC as diameter a circle OA'AFCE'EG is drawn. From the extremity of the diameter C a tangent DD'CBB' is drawn (perpendicular thereto). Now the triangles OA'C and OB'C are similar,

$$\therefore \frac{OA'}{OC} = \frac{OC}{OB'}$$

$$\therefore OA' \times OB' = OC^2.$$

Similarly OA × OB, OE' × OD' and OE × OD are each equal to OC^2. Now with given values of L and C (it is of course understood that these must fulfil the condition that $R = \sqrt{\frac{L}{C}}$) a frequency f_q (termed the "quadrantal frequency") is

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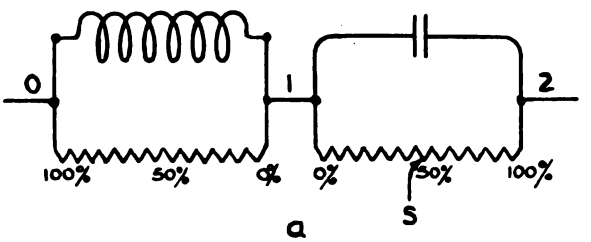
chosen so as to make the admittance of the inductance and condenser elements each equal to that of the resistance elements, i.e., $\frac{j}{w_q L} = jw_q C = \frac{1}{R}$ or

$$w_q = 2\pi f_q = \frac{1}{\sqrt{LC}}$$

Now in the diagram CD at right angles to OC downwards and of the same length



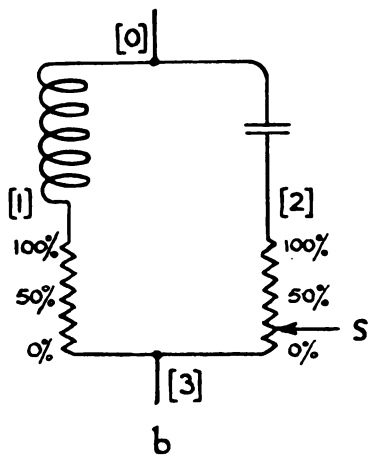


FIG. 1.

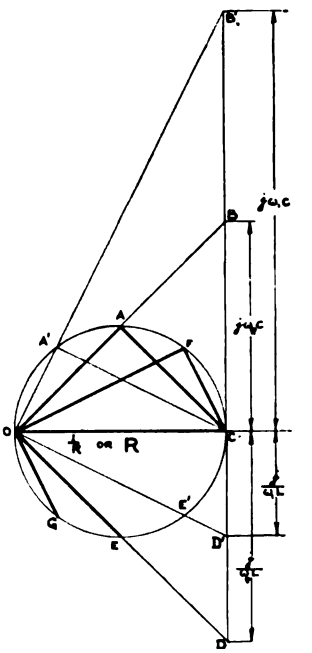


FIG. 2.

represents $\frac{j}{w_q L}$ and similarly CB represents $jw_q C$. Now it is clear that OD the vector sum of OC and CD represents the total admittance of the inductance and resistance in parallel. Now $OE \times OD = OC^2$

$$\therefore OE = \frac{OC^2}{OD} \text{ or } \frac{1}{OD} = \frac{OE}{OC^2}.$$

Now as OC has been made equal to $\frac{1}{R}$, $\frac{1}{OC^2}$ will be equal to R^2 and $\frac{1}{OD}$ will be equal

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to OE $\times$ R^2. Thus the impedance 0—1 may numerically be represented by the length of the line OE multiplied by the constant R^2. As inversion of a vector involves changing the sign of its angle it will be found that the vector may be completely represented by R^2 times a line of the same length as OE and making the same angle with the diameter OC but in the opposite semi-circle, i.e., by $R^2 \times$ OA. Similarly the impedance of the capacity section 1—2 may be represented by $R^2 \times$ OE. The vector sum of OA and OE is OA plus AC and is equal to OC, and it will therefore be found that R^2 times OC represents the total impedance 0—2. Now OC has been made to represent $\frac{1}{R}$, therefore the impedance 0—2 is equal to $R^2 \times \frac{1}{R}$, or R. The construction is also shown for a frequency twice the quadrantal frequency at which the inductive admittance CD' has halved whilst the capacitative admittance CB' has doubled. The impedance 0—1 is then represented by R^2 times OF and that of 1—2 by OG $\times$ R^2 the vector sum of the two being R^2 times OC, or R, as before. Similar constructions may be applied to any and all frequencies and will show that the total impedance is, for the values of C, L, and R defined above, non-reactive and equal to R. A closely similar construction applies to the case shown in Fig. 1B. In this case the total impedance of each branch limb has first of all to be found. These then have to be inverted into admittances and added. The nett result is that the vector OC is first made to represent a resistance R, and the construction finally shows that it also represents the admittance [0]—[3] as a pure conductance $\frac{1}{R}$. Thus it establishes the fact that the impedance [0]—[3] as in the other case is at all frequencies a resistance R.

Further consideration will show that for the case of Fig. 1A the circle in Fig. 2 may be regarded as a locus diagram. The top semi-circle indicates the locus of the impedance 0—1, the bottom semi-circle that of the impedance 2—1. For the top semi-circle, the impedance 0—1 is obviously zero at zero frequency and becomes R at infinite frequency. In the case of the bottom semi-circle the impedance 2—1 is R at zero frequency dropping to zero at infinite frequency. In both cases the rotation of the locus point is anti-clockwise as the frequency is increased. Similarly referring to Fig. 1B the top semi-circle (again treating point O as the origin) is the locus of the admittance of the limb [0]—[2]—[3] starting from 0 as zero frequency, whilst the lower semi-circle is that of the inductive limb C being zero, [0]—[1]—[3], and O infinite frequency. In both cases again the rotation of the locus point is anti-clockwise as the frequency is increased.

In making the construction the term "quadrantal frequency" was used. It is clear from an inspection of the diagram that at this frequency the vector OA is in quadrature to AC for the upper semi-circle case, and similarly OE and EC

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are in quadrature for the other semi-circle, hence the term " quadrantal frequency."

In Fig. 3 is shown an extension of the construction which may be interpreted in the following manner. The circle OA'AFCE'EG corresponds with the circle in Fig. 2. The lines drawn from C refer to frequencies, which are marked where they cut the outside circle, and they only refer to the case illustrated, where for

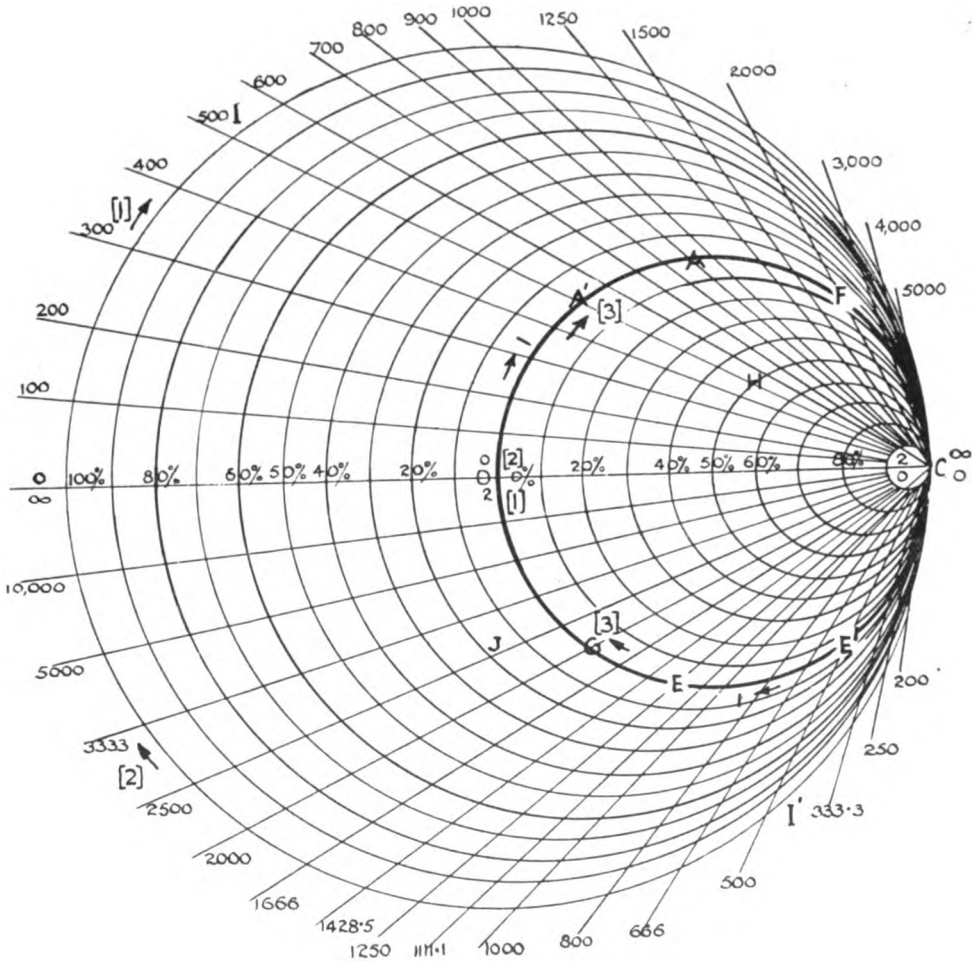

FIG. 3.

simplicity a quadrantal frequency of 1,000 cycles has been chosen. The meaning of the other circles, which it will be noticed are all mutually tangential at point C will now be explained. Considering Fig. 1A, the vector OC represents the impedance 0—2, and the semi-cricle OA'AFC is the locus of the impedance 0—1. Now imagine the resistance between 1 and 2 converted into a potentiometer the relative distances

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from the ends being considered in the manner indicated. Now suppose the tapping point or slider was fixed half-way along or at 50 per cent., how can we find at any frequency the vector potential 0—S ?

Now Fig. 3 can be interpreted as a diagram from which the relative potential between any two points may be read off. The numbers in ordinary type refer to the conditions for 1A, those inside square brackets for those of 1B. In the former case those just above the main diameter refer to that diameter but for the conditions of the top semi-circle, while those just below it similarly refer to the conditions appropriate to the bottom semi-circle. The numbers adjacent to arrows refer to a movable locus point, its position at any frequency being defined by the lines radiating from C. Thus, for example, at a frequency of 500 cycles, if OC or 02 represents the potential 0—2, the potential 0—1 may be found by joining O with the place where the locus 0—1 cuts the 500 cycles line, or A'. Similarly A'C for the same frequency represents the potential 1—2. Now when the slider S is half-way along the resistance between 1 and 2 it is clear that its potential may be found by going half-way down the vector A'C to point H. If this construction be carried out for other frequencies it will be found that the locus of the potential S when S is placed 50 per cent. along the resistance, is the small top semi-circle marked 50 per cent. The potential 0—S may then be found by joining O with the intersection of the appropriate frequency line with this semi-circle. Similarly for any other position of the slider the locus can be found by drawing a semi-circle in the correct relative position. A series of circles inside the main circle and co-diametrical with OC and tangential at C may then be said completely to represent vectorially the potential between any two points in the system of Fig. 1A.

The conditions of Fig. 1B have to be rather differently considered. Now for a given applied E.M.F. between [0] and [3], the currents in the limbs [0][1][3] and [0][2][3] are just proportional to the admittances of these limbs. Again the vector potentials [3]—[1] and [3]—[2] are the products of these currents multiplied by the resistances. These potentials may then be represented by the corresponding admittance vectors for the respective limbs. A little consideration will show that on the same scale as these vectors represent the potentials, the line OC represents the applied E.M.F. across [0]—[3]. There are several ways in which the diagram can be applied to the conditions of 1B, but perhaps the most interesting is the one given below. At infinite frequency the potential [2]—[3] will equal the applied potential [0]—[3] and it will diminish to zero at zero frequency. The top semi-circle will be found to represent the locus of the potential [2]—[3], [2] being the origin O and [3] the point on the semi-circle, which moves anti-clockwise from O as the frequency increases. Similarly the bottom semi-circle is the locus of the potential of [3] relative to [1] as the origin. Considering the potential [2]—[1], how may this be obtained from the diagram ? For clearness let us examine a specific example say for a frequency of 500 cycles. The potential required is made up of

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[2]—[3] + [3]—[1]. Now [2]—[3] is OA′ and as [1]—[3] is A′C ([2]—[3] + [1]—[3] equalling the applied potential [0]—[3]) it will be seen that [3]—[1] is a line equal in length to A′C but in the opposite direction, or AI, where I is a point on the biggest circle. The potential [2]—[1] is therefore expressed by the vector OI. Similarly for the same frequency the potential [1]—[2] = [1]—[3] + [3]—[2] is expressed by OE′ + E′I′ = OI′, which is equal and opposite to OI as it should be. Again it will be found that the other circles represent the locus of points tapped along the resistances, e.g., for a frequency of 2,500 cycles and when the slider S is

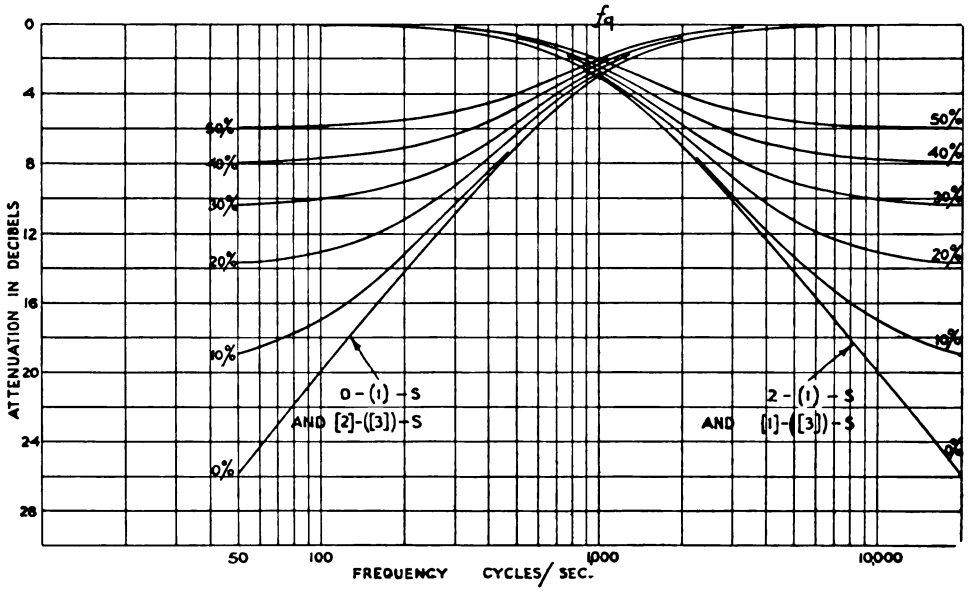

FIG. 4.

20 per cent. up the resistance [3]—[2] the point S would be represented on the diagram by J, which is the point at which the outer 20 per cent. circle cuts the 2,500 line, and the potential [1]—S by the line OJ. It is clear that the vectors [1]—[2] and [2]—[1] swing completely through 180°, as the frequency changes from zero to infinity, without changing in amplitude. The locus of [1] with respect to [2] as origin is the top semi-circle, and that of [2] with respect to [1] as origin the bottom semi-circle, and in both cases and as before the locus point moves anti-clockwise for increasing frequency.

It is clear that the construction shown in Fig. 3 provides a ready graphical means of calculating at any frequency the relative potential between any two points in Figs. 1A and 1B. The curves shown in Figs. 4 to 9, which show the relative amplitude to the applied potential in decibels and also the phase angle in degrees

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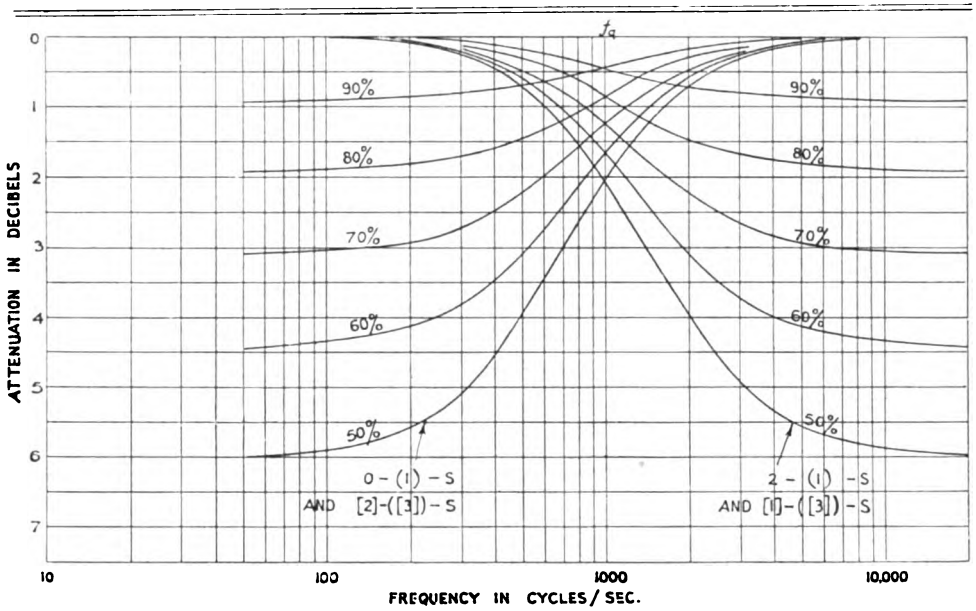

FIG. 5.

for the various tapping positions both for the cases 0—(1)—S, 2—(1)—S of 1A, and [2]—([3])—S and [1]—([3])—S of 1B. The basic curves so obtained can be applied

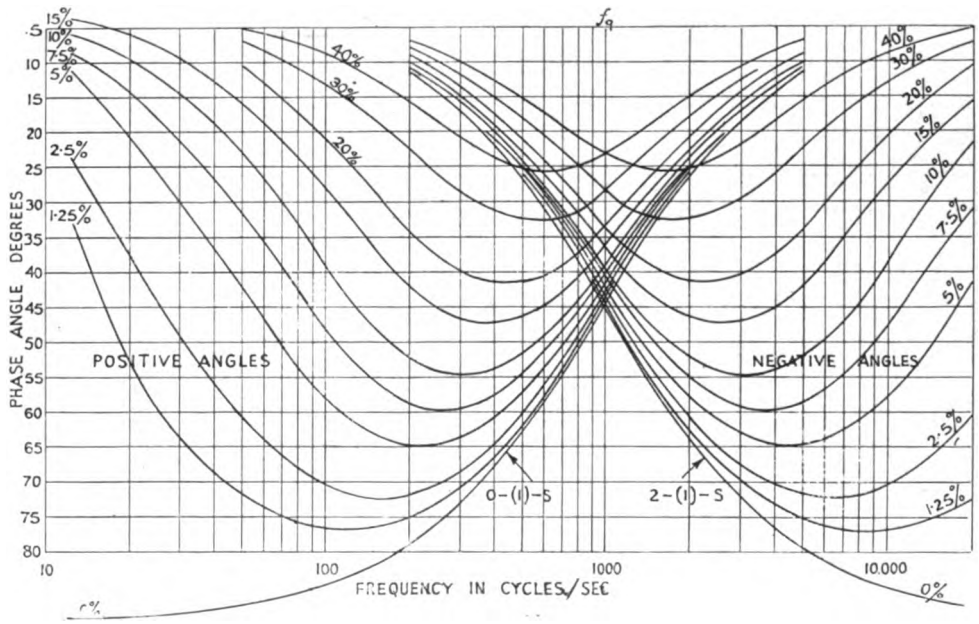

FIG. 6.

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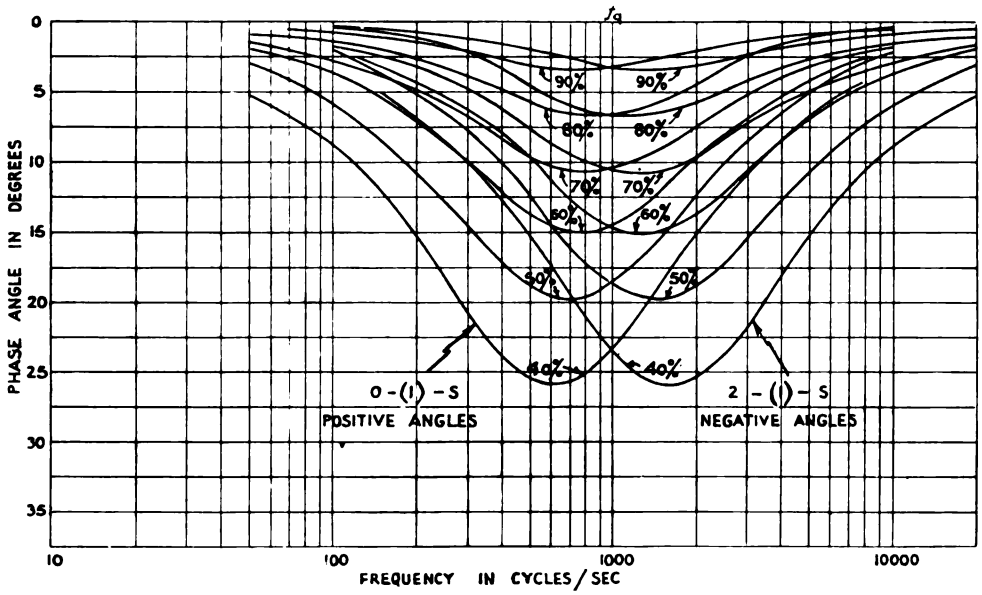

FIG. 7.

not only for cases worked out, where the quadrantal frequency has been assumed to be 1,000 cycles, but as will be shown below they are readily adaptable to other

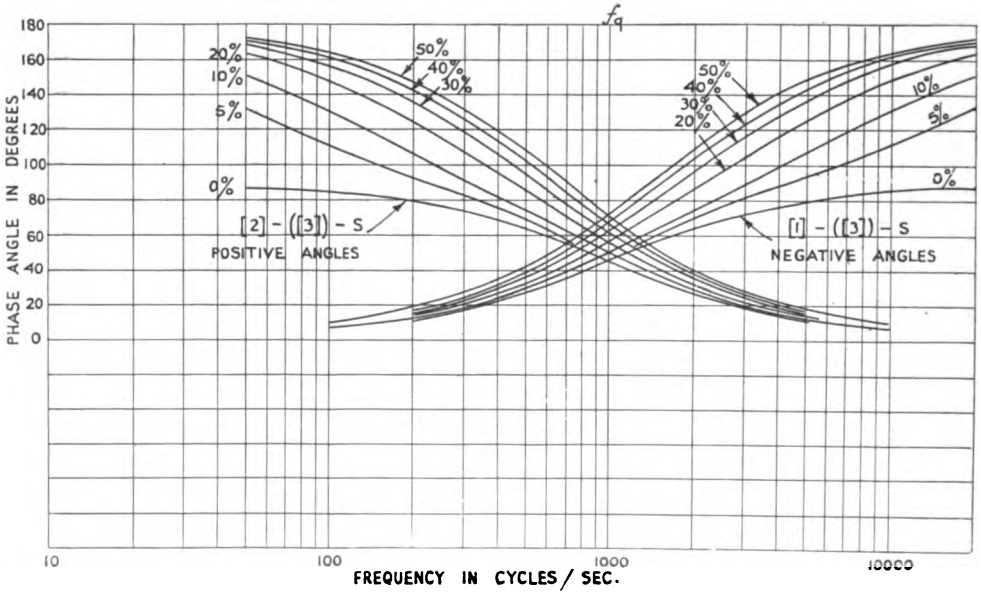

FIG. 8.

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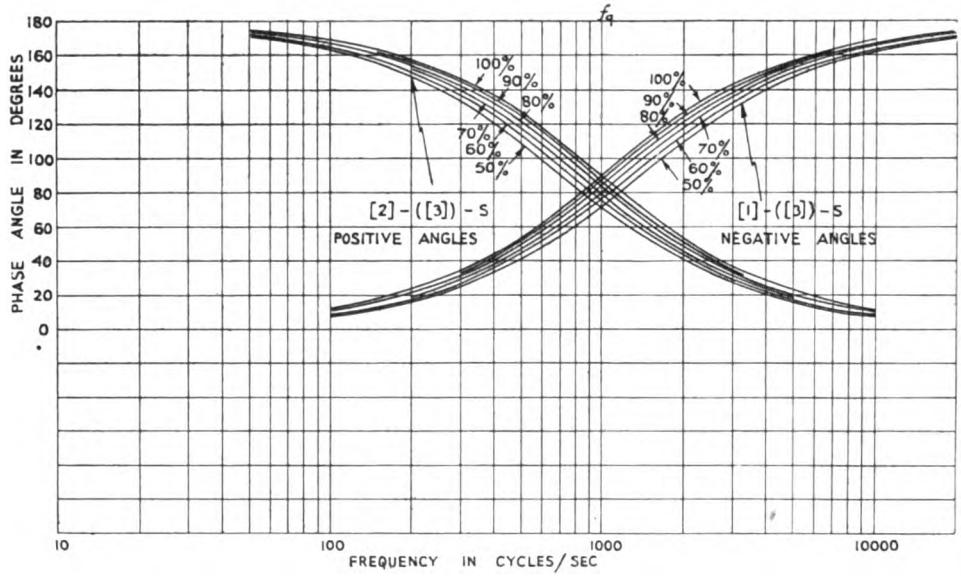

FIG. 9.

quadrantal frequencies. Also it is possible by circuit combinations to multiply the attenuation effects, and by the use of resonant arms correctly designed to make the attenuation effects take place over a relatively narrow frequency spectrum, but before considering the more complex types of circuit it will be well to examine the basic circuits already considered in relation to the group of curves.

Considering 1A, if a variable frequency of constant E.M.F. were applied at terminals 0 and 2 and readings were taken of the voltage 0—(1)—S (where the symbol 0—(1)—S is employed to indicate that the point 1 is between 0 and S) through the frequency range for various positions of the slider S and a series of curves plotted in which these results were shown, the curves in Figs. 4 and 5 would be produced, allowing for some deviation from the theoretical curves due to the resistance of the inductance and condenser and in some cases due to the fact that the voltmeter used to read the output voltages might not be of negligible resistance in comparison with the resistance R. As the slider is moved along from 0 per cent. to 100 per cent., the locus point which defines the potential of S sweeps out smaller and smaller circles until when it reaches 100 per cent. it is stationary at C indicating that the voltage is just that of the applied voltage at all frequencies. Thus as the tapping point moves up the attenuation range is decreased, while it will be found that at 0 per cent. in the theoretical case infinite attenuation is reached at zero frequency, whilst when the slider is moved to 20 per cent., for example, the amplitude at the lowest frequencies does not fall below 20 per cent. of the applied E.M.F. Another effect which is also clearly illustrated by the curves and may be

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graphically interpreted from the diagram is that at the higher tappings the curves more rapidly approach their assymptotic values as the frequency is decreased. If the curves are plotted on a logarithmic frequency scale, as is shown, an exactly symmetrical set of curves, relative to the quadrantal frequency axis, are obtained for the case showing the voltage 2—(1)—S, but with attenuation increasing as the frequency is raised.

Similarly for Figs. 6 and 7, the phase angle curves are symmetrical to each other as the frequency scale is logarithmic, but the scale for one group of curves must be interpreted to read positive angles, and the other negative angles. It will be noticed that the phase change never exceeds 90° and that for each tapping a maximum phase angle is reached. The frequency at which this maximum occurs swings across the higher attenuation range of the curves as the tapping percentage is increased and at high percentages tends to the quadrantal frequency. An inspection of Fig. 3 shows that this is clearly to be expected.

The same set of curves show the attenuations in the cases corresponding to 1B; the curves attenuating at the lower frequencies referring to case [2]—([3])—S and the other set to [1]—([3])—S. On the other hand the phase angle curves are completely different as the phase alteration through the frequency range is 180°. In general in the practical application of the circuits the basic circuits corresponding to 1A are used where amplitude correction is desired, and those of 1B are used where phase or combinations of phase and amplitude correction are desired.

Although the curves have been drawn out for the case of a quadrantal frequency of 1,000 cycles, they are readily adaptable for other quadrantal frequencies, as they are drawn to a logarithmic frequency base and hence their shape does not alter as the frequency range is changed. An illustration of how they are applied in a specific case will make this clear. Suppose a circuit required correcting in a definite frequency band and it was found that the simplest form of circuit would meet the requirements. Its attenuation curve would be plotted out to the same scale, both in attenuation, and in the logarithmic frequency scale, as the group of curves to be used for correction, but with attenuation in decibels, plotted upwards. The curve would then be traced on transparent paper marking the axes and a few frequency lines and the curve superimposed on the group of curves and slid over them until a curve of the same shape over the range of correction required was found (taking care to keep the ordinate axes parallel all the time). The quadrantal frequency line from the group of curves beneath would then be traced through and by replacing the traced curve over the original the quadrantal frequency corresponding to these conditions would be read off on the frequency scale beneath. More complicated cases are worked out on the same general principles.

(*To be continued.*)

N. M. Rust.

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TRANSATLANTIC WIRELESS ANNIVERSARY

INTERNATIONAL "ROLL CALL" TO CELEBRATE FIRST LONG DISTANCE WIRELESS SIGNAL OF THIRTY YEARS AGO

TRIBUTES TO MARCHESE MARCONI

SATURDAY, December 12th, was the thirtieth anniversary of the historic wireless experiment conducted by Marchese Marconi between the Poldhu wireless station, in Cornwall, and St. John's, Newfoundland, which resulted in the transmission and reception of the first wireless signal across the Atlantic.

The long distance wireless communication thus inaugurated by Marchese Marconi has grown, in the intervening thirty years, to a world-wide system of wireless stations covering every country of importance in the world. The original scope of wireless has also been very considerably extended. One of the first of its principal uses was in organising communication between ships at sea and the shore, and it is hardly necessary to refer to the inestimable advantages which shipping and all connected with it has enjoyed from the adoption of this system of communication. Safety at sea has been enormously increased and navigation has been aided in many ways by its use. For business and pleasure wireless has now become an integral part of a ship's equipment, and to-day there are few ships which have not a means of immediate and continuous communication with land.

Three thousand British ships carry Marconi wireless apparatus to-day, and many thousands more carry wireless apparatus supplied by other national companies which owe their existence to his genius. The number of lives and the amount of property saved by Marchese Marconi's invention is incalculable. Aerial navigation too, analogous as it is to ocean travel, has benefited from wireless communication which is now an essential part of the organisation of commercial air routes.

In scientific work, surveying, exploration, in fighting forest fires, in linking up lightships and lighthouses with harbour authority headquarters, in providing communication by telephony and telegraphy for isolated settlers, for naval and military purposes, and for bringing amusement into the homes of every member of the community, wireless has shown itself to be of almost unbounded application and usefulness. For all this, while not forgetting that many other inventors have made valuable contributions to the science and art of wireless, congratulations are due to Marchese Marconi, the pioneer of commercial wireless communication, on the celebration of this thirtieth anniversary.

Mr. David Sarnoff's Tribute to Marconi.

The occasion was celebrated by a wireless roll call of sixteen nations, organised by the National Broadcasting Company of America on December 12th which was described in the American newspapers as "Marconi Day."

This roll call of the world began in Washington, where Mr. Merlin H. Aylesworth, President of the National Broadcasting Company, introduced Mr. David Sarnoff, President of the Radio Corporation of America, who recalled how a doubting world at the opening of the twentieth century had regarded wireless telegraphy as a dreamer's fancy. He described Marconi as a world benefactor and congratulated him on always continuing in the forefront of the research which followed his first amazing work. "Always imaginative but never visionary, never resorting to bombast or vain prediction, always searching for the practical, he had carried the art of wireless through succeeding steps until at last he had dispatched his signals beyond the wide expanse of the ocean," said Mr. Sarnoff.

"In the history of invention one finds no forward stride more truly the result of one man's inspiration and industry. Countless millions had lived before Marconi. About them through the ages slumbered the force of radio. Destiny had selected this youth of twenty-two summers as its agency for shaking this phenomenon from the wonder-box of nature. It might almost be said that, in winning a new dominion, Marconi wiped out the last frontier that baffled man's penetration and enslaved the infinite mysteries of space itself.

"The manner in which we are paying this tribute is an evidence of the magnificence of Marconi's gifts. A great invention is a key unlocking the door to a new era. One never knows what lies beyond. In his laboratory at Bologna the youth who was rendering serviceable the Hertzian waves could never have envisioned this world-wide broadcast. Yet, step by step the services and facilities have been created that have made it possible. Enterprise, inventive

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1895

His Excellency Marchese Marconi.

1897.

Col. H. Jameson Davis, H. W. Allen, G. S. Kemp.

1898.

F. W. Paget, C. E. Rickard, R. F. Cave,

1899.

W. Densham, Andrew Gray, H. M. Dowsett, R. T. Munson, F. S. Stacey,

F. Woodhouse, C. S. Franklin, P. J. Woodward, A. B. Blinkhorn, M. Travailleur, G. Pérter,

1900.

W. H. Corby, R. N. Vyvyan, A. J. Clark, F. Archer, J. Harvie Clark,

Sir Ambrose Fleming, A. H. Atkinson, E. E. Triggs,

1901.

W. S. Entwistle, W. J. Willey, G. H. Green, A. Eve, Capt. C. V. Daly, G. Pells, E. G. Tyler,

F. E. D. Pereira, F. K. May, A. H. Ginman, A. Vanderpooten, R. Poupart, H. E. Dunn, F. Huff,

1902.

E. Berry, W. F. Thomas, R. D. Bangay, F. E. Burrowes, W. Davies, Capt. H. J. Round,

H. A. Ewen, E. C. Richardson, A. A. Kift, J. Lewis, H. E. Watterson, R. G. Newman,

1903.

D. W. Tulloch, J. R. Stapleton, F. Jones, J. Harvey, A. J. Huff, H. T. Worrall, E. T. Hills, L. Verbrugghen

1904

H. J. Tattersall, A. J. Irvene, T. Iddon, W. A. Taylor, W. I. McGhee,

J. R. Robinson, W. Platt, W. J. Collop, W. N. Ball, F. S. Hayburn,

A. Cappelaere, W. Tasker, H. Cornwall, F. Delasse, W. J. Gray

1905

S. C. Parish, J. N. Johnson, W. B. Cole, E. J. Wagstaff, C. A. Manson,

C. A. Mason, H. M. Burrows, C. James, F. W. M. Herring,

A. C. Lewis, G. Ludwig, D. Macdonald, F. R. Pells, E. Horton

1906.

C. J. Ketteridge, Marquis L. Solari, F. Beatson, A. J. Chesterton, E. Hill,

A. M. Young, D. Sutherland, S. Stansbridge, Seton Smith, A. Ashley, W. Rogers,

F. Baker, S. C. Hills, C. C. Howe, H. D. Humphries, R. Leith, J. C. Hawkhead,

S. Kent, A. Fournier, A. Maernoudt, Annie König, M. J. Tasteney, R. C. A. Kroes.

Roll of Marconi Veterans, 1931.

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effort and perseverance have characterised nobly the efforts of those who have builded upon Marconi's first idea; but to him are we primarily indebted.

The International Significance of Wireless.

"This broadcast to sixteen different nations is a demonstration, then, of the world's technical advancement as a heritage from Marconi's genius. It is likewise evidence of a greater contribution to world progress in which radio is but the instrumentality, the symbol. I refer to the increasing role radio is playing in the exchange of opinions between nations, in the universal understanding in such world tributes as this to-day to a world figure. Within the last fortnight we have heard the first debate between representatives of Oxford and Harvard Universities—dealing with a topic of vital public interest in Europe and America—transmitted on the radio trail blazed across the Atlantic by Marconi thirty years ago.

"Radio is the medium by which we may learn to appreciate the thoughts and aspirations of other peoples. What we have already had in international broadcasting is but an indication of how the force unloosed by Marconi may bring the people of the world into a new and closer relationship. Long years of effort and the expenditure of hundreds of millions of dollars in the interest of world amity could not so readily promote the cause of lasting peace as the work of this one inventor. Four hundred years earlier Marconi's compatriot Columbus annihilated an ocean barrier and found a new continent; Marconi annihilated the barrier of space and discovered the neighbourhood of nations.

In the Vanguard of Radio Progress.

"I must say one other thing of Marconi. After the passing of three decades since he spanned the sea with wireless, he remains in the vanguard of radio progress, and to-day is giving to the world the results of his invaluable research in the field of ultra-short wave transmission. Being the true scientist, he has never been content with the immortality already won. On behalf of the industry with which I am associated and on behalf of the great number of workers who have struggled constantly to enlarge the scope and service of radio, I congratulate Senatore Marconi on the thirtieth anniversary of his great accomplishment. I have always been proud to call him my teacher and my friend."

The scene then shifted to London where Sir John Reith, Director-General of the British Broadcasting Corporation, introduced Marchese Marconi to his world-wide audience and said that in addition to the credit due to him for the commercial development of wireless which had effected a revolution in communications, he was to be honoured for the trait in him which impelled him ceaselessly to new experiments. There were not many, said Sir John Reith, to whom Gœthe's description of "exact fancifulness" could be more aptly applied than to Marconi. Nor were there many fields of human activity in which the happy combination of exactitude and imagination, such as was possessed by Marconi, were so essential.

Marchese Marconi's Speech.

Marchese Marconi then spoke from Savoy Hill, and, after thanking those who had introduced him for the kind sentiments they had expressed, compared his feelings that day with those thirty years ago when, instead of sitting in a comfortable room in London speaking words which he knew would be received and understood throughout the United States of America and beyond, he was standing in a bitterly cold room on the top of a hill in Newfoundland wondering if he would be able to hear the simple letter "S" transmitted from England.

Marchese Marconi then described the circumstances leading up to his decision to attempt to send a wireless signal across the Atlantic and detect it on the other side and the experiences of himself and his two assistants, Mr. G. S. Kemp and Mr. P. W. Paget, at St. John's, Newfoundland, on that historic occasion thirty years ago. He concluded by tapping out the letter "S" on a telegraph key as he had heard it first across the Atlantic in 1901.

The broadcasting pick-up was then switched to many cities in succession, speakers from the following countries paying tribute to Marconi's genius and achievement:—Belgium—Mr. Maurice Philippson, Director-General of the Institut National Belge de Radiodiffusion; France—M. Guernier, Minister of Posts and Telegraphs; Germany—Dr. Hans Bredow, Commissioner-General of German Radio; Italy—Signor Carlo Formichi, Vice-President of the Royal Italian Academy; Poland—Dr. Zygmunt de Chamiec, Director-General of Polskie Radio; Brazil—Dr. Jose Amerigo de Almeida, Minister of Communications; Japan—Dr. S. Inada, Director-General of Communications; U.S.A.—Dr. Michael Pupin, Major-General Charles McK. Saltzman, Chairman of the Federal Radio Commission, and Mr. Fred Muller, President of the Veteran Wireless Operators' Association; the Philippines—Mr. G. C. Butte, Acting-Governor; Venezuela—General Martinez, Chief of Communications; Argentina—Mr. Octavio S. Pico, Minister of the Interior; Hawaii—Mr. Raymond C. Brown, Acting-Governor; Canada—Mr. Alexander Johnston, Deputy-Minister of Marine.

Dr. Pupin Extols Marconi's Courage.

Dr. Michael Pupin said: "Marconi's letter 'S' was the shortest message ever broadcast across the Atlantic, yet no dispatch had ever carried more significance. No other message

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carried by the wings of the electric waves from the Continent of Europe to that of America had a deeper meaning. But Marconi alone understood its full import ; to him alone the message announced the early dawn of a new epoch of trans-oceanic communications. This awakened in his prophetic mind the vision which guided his great effort along the steep and arduous path which led to the great triumph of our radio art.

" Few of us understood the full meaning of Galileo's simple experiment of 300 years ago, when from the leaning tower of Pisa he dropped little weights and from their motion derived the laws which guide the motion of the planetary system. Few of us understand the full meaning of Marconi's vision which guided the growth of the wireless art from its humble beginning of thirty years ago to its great achievement of the present day. But just as all of us know and admire the sublime courage with which Galileo defended his new science, so all of us know and admire the sublime courage which enabled Marconi to transform his vision of thirty years ago into the beautiful reality of our present radio art.

" Italy can justly be proud of her two great sons, Galileo and Marconi, not only on account of the genius which created the prophetic visions, but also on account of the sublime courage which defended these visions until they became beautiful realities."

Veteran Wireless Operators Present Medal.

The Veteran Wireless Operators' Association of the U.S.A., through its President, Mr. Fred Muller, who spoke at the National Broadcasting Company's studio in New York, presented to Marchese Marconi a gold medal which was accepted on behalf of the inventor by Signor Emanuele Grazzi, Italian Consul-General at New York, and the radio roll call concluded by the relay of the letter " S " round the world from New York to the Philippines, Java, Europe and back to New York.

Marchese Marconi was inundated with telegrams of congratulation on the anniversary from all parts of the world. These telegrams included those from the Italian Foreign Minister, the Italian Senate, the Italian Royal Academy and the Italian National Council of Research.

MARCONI VETERANS' DINNER

The fourth Annual Reunion and Dinner of the Marconi Veterans, comprising members of the staff who had completed 25 years service or more with the Marconi Company, or any of its associated companies, took place at the Holborn Restaurant, Kingsway, London, on Friday evening, November 27th, 1931.

There was a large gathering under the Chairmanship of Mr. C. E. Rickard, O.B.E., and the function was a great success.

Marchese Marconi, who at an earlier date had intimated his intention of attending, was unfortunately prevented by urgent business in Italy from arriving in England in time for the function.

Among those present were Col. Jameson Davis, Mr. H. W. Allen, Mr. Andrew Gray, Mr. C. S. Franklin, Mr. A. H. Ginman, Mr. H. J. Round, Mr. F. S. Hayburn, and others whose names have been well known in wireless for many years.

Telegrams of greetings and good wishes were received from Marchese Marconi, Marchese Solari, Capt. C. V. Daly, Mr. J. Lewis, and three veterans, Messrs. Gray, Dunn and Newman, in Canada, who were meeting at a similar function held by the Canadian Marconi Executives on the same evening in Montreal. Letters were also received from Monsieur M. Travailleur, of Brussels, and many others.

The gathering stood for a moment as a token of respect to the memory of two of their members, Messrs. F. J. Leathers and P. L. Rowland, whose deaths occurred during the year.

After the toast of the King, the Chairman in a short speech proposed the toast of His Excellency Marchese Marconi, from whom, he said, he had received a telegram of greeting, and regret at his unavoidable absence, and to whom he proposed to convey the greetings and best wishes of the Veterans, " that he may long continue to enjoy health, success and happiness." With this toast he coupled the names of " Col. Jameson Davis, our first Managing Director, Marchese Solari, the head of our agency in Italy, and Capt. Daly, our old and esteemed maritime collaborator."

The toast of the new members was proposed by Mr. F. S. Hayburn and replied to by Mr. J. C. Hawkhead. Mr. H. W. Allen proposed the Chairman, to which the Chairman replied.

An excellent musical programme was rendered throughout the proceedings.

All arrangements were as usual carried through by a Committee of Guarantors, for whom Mr. H. M. Dowsett acted as executive and Hon. Secretary, and Mr. Collop as Hon. Treasurer.

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THE MARCONI REVIEW

January-February, 1932

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THE MARCONI REVIEW

No. 34. Jan.-Feb., 1932.

Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.

AN APPLICATION OF THE CIRCLE DIAGRAM TO THE DESIGN OF ATTENUATION AND PHASE EQUALISERS

(PART II.)

In the last number of THE MARCONI REVIEW, *the first part of an article dealing with a new construction of equalising and correcting networks was given.*

This article is concluded in the following pages.

IN cases where the shape of any of the attenuation curves is not suitable to meet any specific requirements the use of more complex circuits is required and there are two methods that can be used. The first is that of multiplying the correction effects. In Fig. 10 the full bold lines indicate a circuit of the type of 1A. Now as a circuit of this type behaves as a resistance at all frequencies, it is clear that the two resistances in the circuit itself may one or both be replaced by similar circuits, and again the resistances in these circuits may be replaced by further circuits and the process may be carried on indefinitely. In Fig. 10 the main circuit shown in thick lines has had its resistances replaced by the circuits shown in thick dotted lines, and the resistances in the latter circuits have in turn been replaced by the circuits shown in thin lines, and finally the resistances of the latter have been replaced by the circuits shown in thin dotted lines leaving the circuit finally bounded by a chain of sixteen resistances, each equal in value to the hypothetical resistances they have replaced, or to $\sqrt{\frac{L}{C}}$. For simplicity in the case being considered the same values of L and C have been chosen throughout, though this need not have been so, a different quadrantal frequency could have been chosen for each circuit so long as the ratio $\sqrt{\frac{L}{C}}$ was made equal to the resistance R, hypothetical in every case but the last set of circuits. Now it is interesting to apply the circle diagram to analyse this case and to assist in doing this the various junction points in the circuit have been numbered and it will be found that the numbers correspond with these on the circle diagrams for the case Figs. 11 and 12. The lines on the two diagrams have been made to correspond also, i.e., thick lines to the circuit in thick lines, etc. Two cases have been drawn out, one for the quadrantal frequency, and one for half the quadrantal frequency.

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The simplest way to consider the diagrams will be to follow them through systematically piece by piece. Thus considering Fig. 11 (drawn for the quadrantal frequency) in conjunction with Fig. 10, the vector 0—8 defines the potential between the points 0 and 8 where 0—16 represents the E.M.F. applied right across the circuit. Similarly to find the potential across the inductance in the next row in Fig. 10 it is necessary to apply to the vector 0—8 the same construction as was applied to 0—16 when 0—8 was obtained, and the result of this operation is the vector 0—4. Similarly from 0—4, 0—2 is derived, and finally from 0—2, 0—1. As the same construction is applied each time the result is that the original vector is divided by the same factor each time the process is applied. In the case considered at the quadrantal

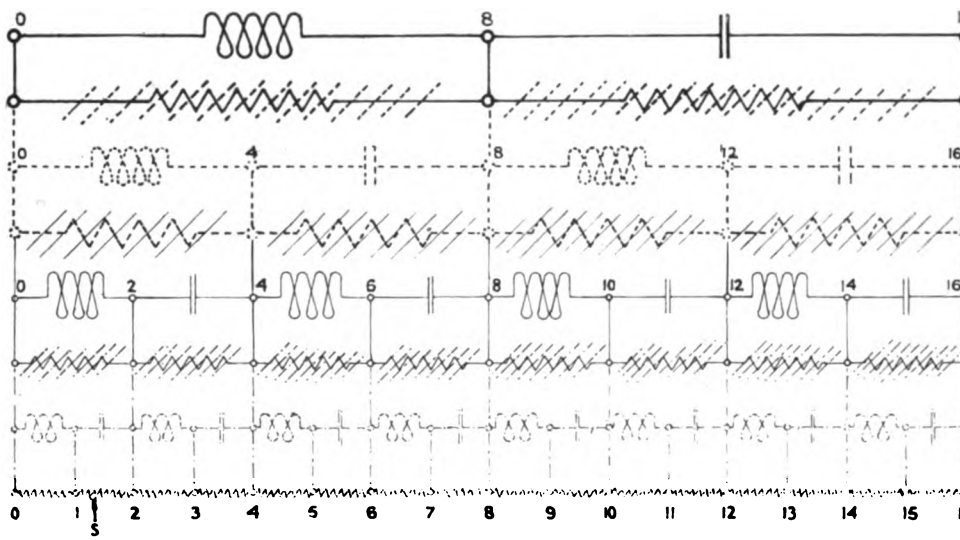

FIG. 10.

frequency and for the circuit arranged as in Fig. 10, with one tapping point remaining at 0, the other being progressively tapped across the first inductance in each row, each time the tap is moved down one row the vector potential is divided by $\sqrt{2}$ and the angle is swung through 45°, as is shown in Fig. 11. In the other case considered which is shown in Fig. 12, it will be seen that the vector is divided by 2 at each step and swung through 60°. The 0 per cent. curve 0—(1) —S on Fig. 4 may be made as explained above, correctly to represent the attenuation at point 8 for any frequency, and the similar curve on Fig. 6 the phase angle. Thus in the case considered where the quadrantal frequencies are all the same, if the ordinates of the frequency and phase angle curves are multiplied by two they represent the potential 0—4, when multiplied by three the potential 0—2, and when multiplied by four that of 0—1. In cases where the quadrantal frequencies of each circuit were different it would be necessary to obtain the correct curve corresponding to the

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quadrantal frequency of the first section, add to it that corresponding to the quadrantal frequency of the next, and so by a series of successive additions obtain the final curve. By using progressively changing quadrantal frequencies at each stage it is possible to expand the range of frequencies over which the attenuation take place.

Remembering that the diagrams Figs. 11 and 12 may for the particular frequencies for which they are drawn, be regarded as a kind of potential map in which the lines joining any two points vectorially represent the potential between them, it will be seen that by a process of step by step addition, or in the cases where the

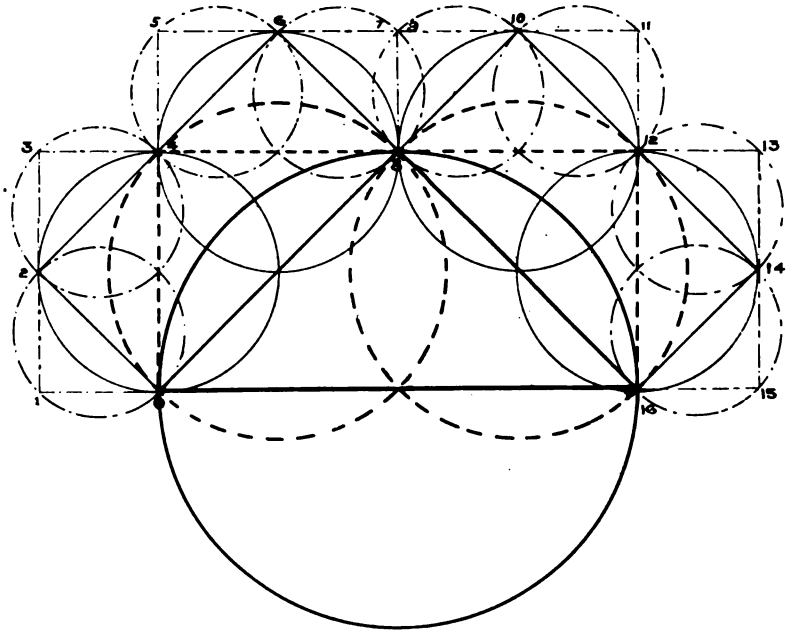

FIG. 11.

same quadrantal frequency is used—multiplication and addition—the potential between any two points at any frequency may be found. To take a specific example, using a simple case for ease of illustration, what is the curve expressing the potential 0—(1)—S at different frequencies, when S is placed 20 per cent. along the resistance 1—2 ? It is clear that the relative potential of 0—(1)—S to 0—2 is expressed by the 20 per cent. curve 0—(1)—S of Fig. 4. Now the potential 0—2 may be obtained as explained from the 0 per cent. curve by multiplying the ordinates, expressing attenuation in decibels, by three. Therefore the complete process is multiply 0 per cent. curve by three and add 20 per cent. curve 0—(1)—(S). In practical cases where the circuits are used to produce a certain required correction curve, and a multi-stage circuit is found to be necessary, it is usually possible to simplify them considerably and still allow a wide margin of adjustment. For example a correction

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between 3 and 4 times the 0 per cent. correction 0—(1)—S Fig. 4 might be required, would be provided by the arrangement 0—(1)—S, of Fig. 10, where S is a movable tapping point or slider, to provide a ready means of adjustment. Now it is clear that to meet these specific requirements the circuit could be simplified to the form shown in Fig. 13.

It is clear that arrangements of circuits may be devised, using the principles enunciated, to meet a large number of correction requirements, but conditions may

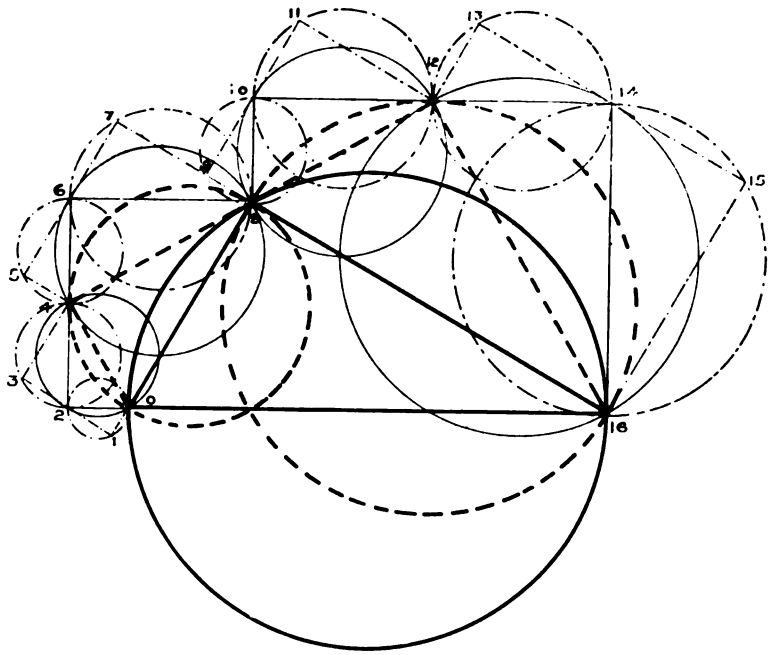

FIG. 12.

arise in which it is necessary to produce correction effects over a relatively narrow frequency spectrum and it is for these conditions that the resonant arm circuits find application, and the theory of these circuits will now be developed. The principles involved are very simple and are based on the fact that below its resonant frequency a series resonant circuit behaves as a condenser, and a parallel resonant circuit as an inductance, and that at any *actual* frequency below resonance an *equivalent* frequency may be derived, this equivalent frequency being the same for both the series and parallel cases, from which and the *capacity* of the series resonant circuit and the *inductance* of the parallel resonant circuit may be worked out the impedance of these circuits by merely replacing the equivalent frequency for the actual frequency, in the usual expression for the impedance of the capacity and inductance. Similarly, above the resonant frequency the series arm may be treated as an inductance of the same value as the inductance of the circuit but behaving

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at another equivalent frequency and this same equivalent frequency will define the impedance of the parallel resonant circuit by considering it as acting on the condenser of that circuit.

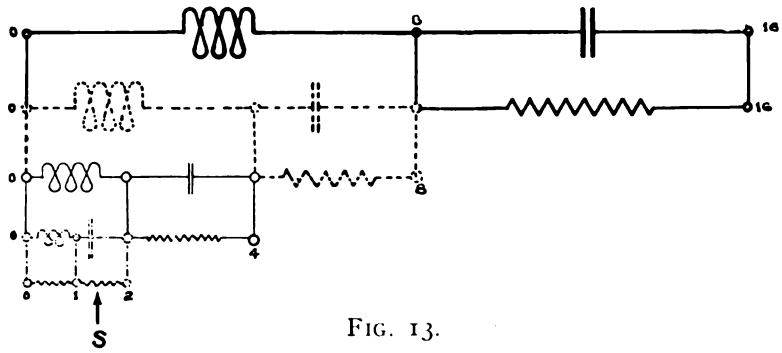

FIG. 13.

In order to define the angular velocities corresponding to the various frequencies clearly let us use the following symbols :—

ω_o the angular velocity at *resonance*.
ω an *actual* angular velocity below resonance.
ω' the corresponding *equivalent* velocity.
ω_q an *actual* quadrantal velocity below resonance.
ω_q' the *equivalent* quadrantal velocity from which this is derived,

and similarly

ω_1 an *actual* velocity above the resonant frequency.
ω_1' its *equivalent* velocity.
ω_{1q} an *actual* velocity at the quadrantal frequency above resonance.
ω_{1q}' the *equivalent* quadrantal velocity from which this is derived.

That is, the suffix $_o$ is used for resonance, the other suffixes being $'$ for equivalent velocities, $_q$ for quadrantal velocities, and $_1$ for velocities above resonance, and these latter suffixes may be combined as required.

Now consider Fig. 14A which corresponds to Fig. 1A, in which the circuits L_1C_1 and L_2C_2 are resonant to the same frequency. Now below this resonant frequency L_1C_1 behaves as a condenser acting at an equivalent frequency ω', its impedance being $\frac{j}{\omega' C_1}$, whilst the circuit L_2C_2 acts as an inductance the impedance of which is defined by $j\omega' L_2$ where

$$\omega' = \frac{\omega\omega_o^2}{\omega_o^2 - \omega^2}.$$

Again above the resonant frequency the circuits L_1C_1 and L_2C_2 behave as an inductance L_1 and a condenser C_2 respectively, both acted upon by an equivalent frequency ω_1' which is derived from the actual frequency ω_1 by the relation

$$\omega_1' = \frac{\omega_1^2 - \omega_o^2}{\omega_1}$$

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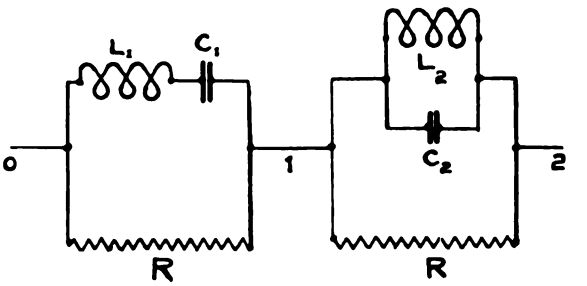
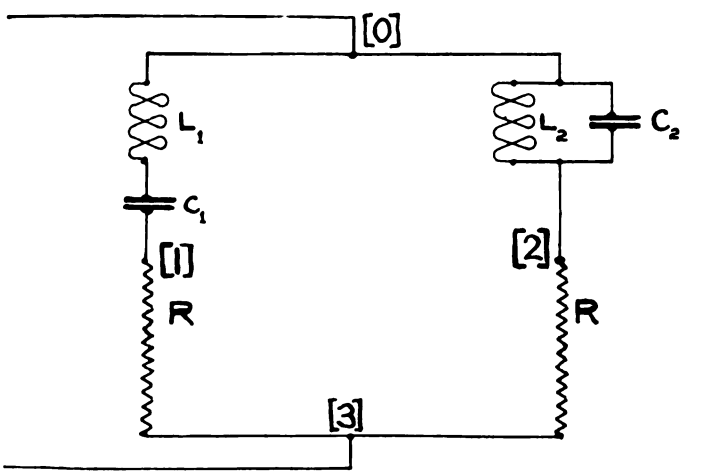
Therefore in the first case (below the resonant frequency) if $\sqrt{\frac{L_2}{C_1}}$ and the second case (above the resonant frequency) $\sqrt{\frac{L_1}{C_2}}$ are each made equal to the resistance R, constant impedance conditions will be realised. It will be found that if the circuits



(A)



(B)

FIG. 14.

are both resonant at the same frequency, or $\sqrt{L_1C_1}$ equals $\sqrt{L_2C_2}$, that $\sqrt{\frac{L_2}{C_1}}$ then equals $\sqrt{\frac{L_1}{C_2}}$ and constant impedance conditions can be met at all frequencies below or above resonance. At resonance it is clear L_1C_1 will be zero impedance, L_2C_2 infinite, and the net result will be that the over-all impedance will still be equal to R.

It is obvious that there are two quadrantal frequencies, one below and the other above the resonant frequency, the former being defined by the relation that

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the equivalent quadrantal frequency w_q' equals $\sqrt{\frac{1}{L_2C_1}}$ and in the latter case $w'_{1q}' = \sqrt{\frac{1}{L_1C_2}}$.

The circle of Fig. 15 is the locus of point 1 in Fig. 14A. The suffixes used are to be interpreted the same way as those applied to the angular velocities. The fundamental conception from the point of view of the circle diagram is the equivalent frequency in each case: the actual frequencies are shown in brackets. It will be seen that at zero frequency the L_1C_1 branch is open circuit and the L_2C_2 short circuit so the full potential is across o--1, the locus point, therefore, as the frequency is

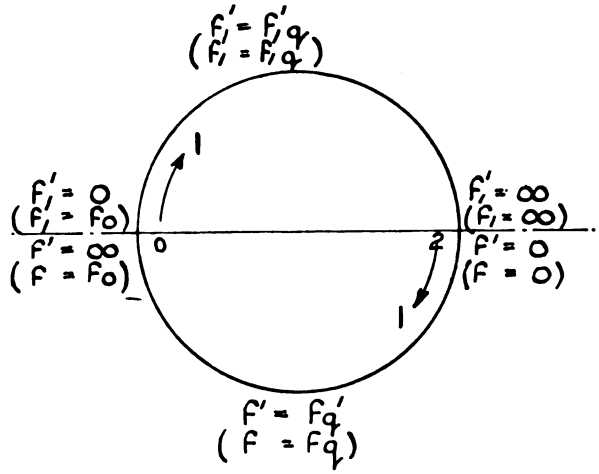

FIG. 15.

raised from zero, starts from 2 moves round the bottom semi-circle anti-clockwise through the first equivalent quadrantal frequency to the origin which is reached when the equivalent frequency is infinity the actual frequency then being the resonant one. As the frequency is raised from resonance, which is an equivalent frequency of zero for the conditions applying above resonance, the locus point sweeps out the top semi-circle through the second equivalent quadrantal frequency back to point 2 when both equivalent and actual frequencies become infinite. It is quite easy to apply the curves to meet any given set of conditions including those involving tapping positions on the resistances and in general it will be found that if one curve of the group represents conditions below the resonant frequency the companion and symmetrical curve to it sloping in the other direction will represent conditions above resonance.

Considering the two quadrantal frequencies it is quite clear that they are interrelated, and it is easy to show that they are logarithmically symmetrical to the

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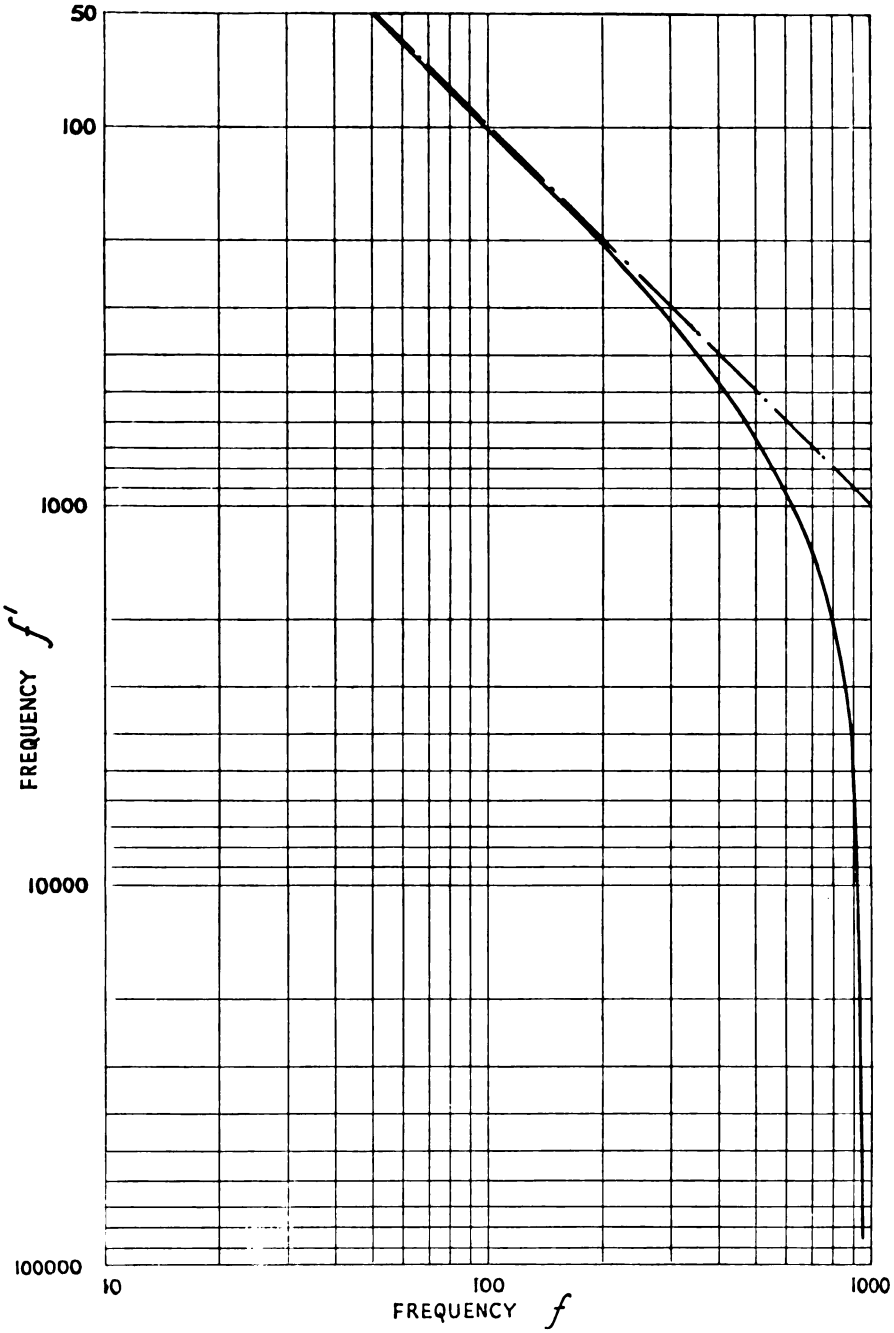

FIG. 16 (A).

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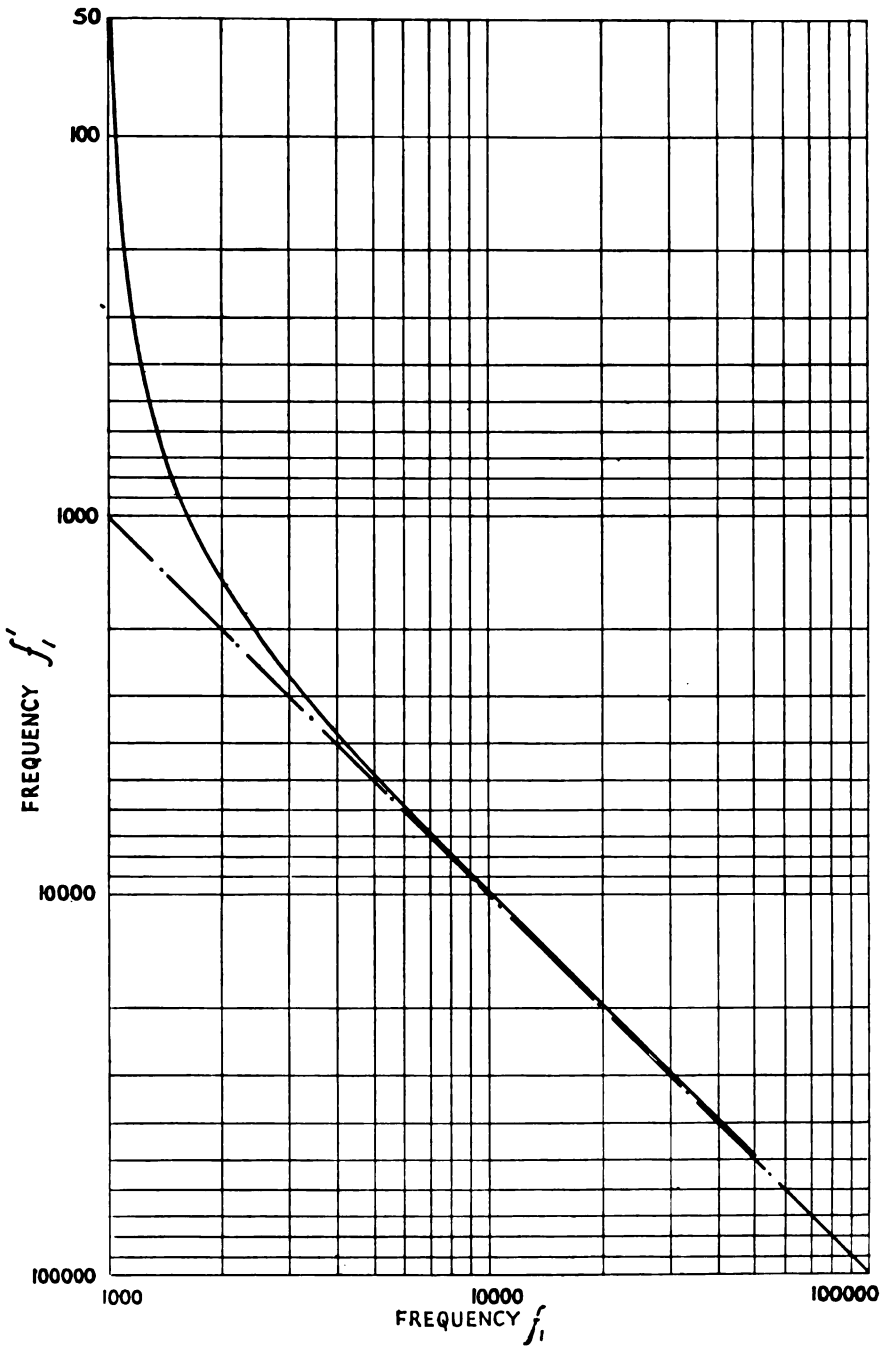

FIG 16 (B).

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resonant frequency. Now, remembering that the ratio of L_1/C_2 and L_2/C_1 are fixed by the resistance R, and that the product L_1C_1 must equal L_2C_2 and is fixed by the resonant frequency, the ratio of L_1 to C_1 can still be altered, any alteration involving an opposite alteration in the ratio of L_2 to C_2, and a little consideration will show that big ratios of L_1 to C_1 accompanied by small ratios of L_2 to C_2, move the actual quadrantal frequencies relatively nearer the resonant frequency, whereas small ratios of L_1 to C_1 with large ratios of L_2 to C_2 make these frequencies remote from the resonant frequencies. Alteration of these ratios to suit the conditions required thus afford a means of altering the frequency spectrum in which the effects are required to become operative.

In many cases where the resonant arm correction is used the resonant frequency is put outside the correction range so that only one group of curves comes into action. In plotting the resonant arm curves use has to be made of a curve defining the actual frequencies in terms of the equivalent ones, as the group of curves Figs. 4 to 9 is in terms of equivalent frequencies when applied to resonant arms. Such a curve is shown in Figs. 16A and 16B, 16A giving the equivalent frequency f' in terms of the actual frequency f_1 for frequencies below resonance, whilst 16B shows the relation of f_1' to f_1, the equivalent to actual frequency above resonance. In both cases the resonant frequency is 1,000, but as the scales are logarithmic the curves can be made to apply to other resonant frequencies by the following construction, which applies to both cases. Upon the diagram mark a hypothetical point f' or f_1' as ordinate, and $f = f_o$ as abscissa. Through this point draw a vertical line and a 45° degree line parallel to the dotted asymptote line to which the curves tend at frequencies remote from resonance. Now on tracing paper, trace out the curves from 16A or 16B and the 45° asymptote line and the vertical axis at 1,000 cycles, and slide this curve over the curve over 16A or 16B until the asymptote ordinate axis coincide with the ones marked for the new resonant frequency. The required frequencies can then be read directly from the traced curve using the squares and scales of the curve beneath.

It will be found that the nearer the quadrantal frequencies are placed to the resonant frequency, the more care will be required to be taken to keep coil and condenser losses down in order to make practical results accord with theoretical.

Referring to Fig. 14B, which is the counterpart of Fig. 1B, it will be clear that the outer circles of Fig. 2 can be made to express the relative potential conditions, and that the vectors [2]—[1] and [1]—[2] sweep right round the outer circle, or through 360° as the frequency is changed from zero, through resonance, to infinity.

Combinations including resonant arm circuits designed in the above manner may be treated in multiple in an exactly similar way to the basic circuits, and may have if required different resonant and quadrantal frequencies for each sub-circuit.

N. M. Rust.

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WIRELESS TELEPHONE INSTALLATION ON THE "MONARCH OF BERMUDA"

The new liner "Monarch of Bermuda," owned by Messrs. Furness Withy & Co., which was built by Messrs. Armstrong Vickers at their naval yard, Newcastle-on-Tyne, left England on the 14th November, 1931, for New York to take up her service on the New-York-Bermuda run.

The radio telephone installation on this ship was carried out by the Marconi Co., and is briefly described in the following article.

THE Transmitter installed on board the "Monarch of Bermuda" is the Marconi Type S3B, a full description of which has been given in THE MARCONI REVIEW, No. 28. For the purpose of this article, however, we shall briefly summarise the main points of this transmitter below.

The Receiver is the Marconi Type RC45 which is similar to that installed on the "Empress of Britain" and described in THE MARCONI REVIEW, No. 32.

In the case of the "Monarch of Bermuda" 2 wire working is not employed, and in place of telephones being installed throughout the ship, a single telephone booth is erected near the purser's office where all subscribers' calls are connected.

Immediately after leaving England a communication was established with America and an excellent commercial circuit has been maintained.

The Transmitter.

The transmitter is capable of working on any wavelength between 20 and 120 metres, and is also provided for crystal control on 4 spot waves of 71·8, 71·18, 33·9 and 34·94, these 4 crystal wavelengths being those used by the ship on the Bermuda run. The power of the transmitter is rated 160—180 watts to the aerial for telephony, and 300 watts on continuous wave transmission.

A photograph of the Transmitter is shown in Fig. 1 and consists of a master oscillator with crystal control on 4 spot waves as has been mentioned above, master oscillator amplifier and 2 stages of power amplification shown as No. 2 and No. 1 magnifier in the schematic diagram given in Fig. 2. The standard type S3B transmitter has been suitably modified to include a carrier suppressor unit which cuts off the carrier of the transmitter when the subscriber ceases to speak and is rendered necessary by the fact that the transmitter is in close proximity to the receiver. The master oscillator box is situated on the right hand side of the transmitter and, together with the 4 spot crystal frequency circuits, is enclosed in a metal screened

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box and heated by heater lamps off the main D.C. supply. The temperature of the interior of the box is maintained constant by means of a thermostat at 140° F.

The use of this thermostatically controlled master oscillator ensures that the frequency of the telephone carrier is kept constant when modulating, thus facilitating transmission and avoiding any distortion which may arise due to carrier wobble when working on short waves.

Any one of the 4 spot crystal waves can be selected by a simple change over switch on the master oscillator box.

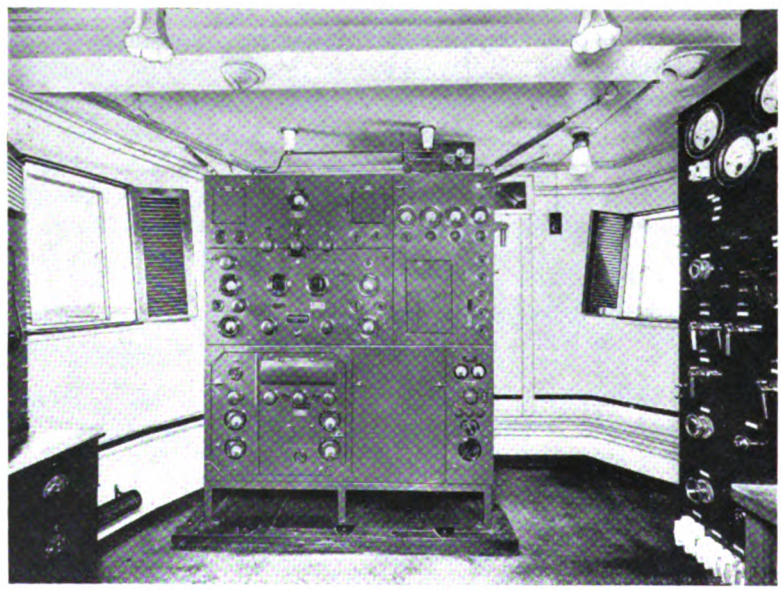

FIG. 1.

The output from the master oscillator is amplified by means of the master oscillator amplifier which comprises 6 valve stages indicated on the schematic diagram as :—isolator, 1st, 2nd, 3rd, 4th and 5th bridges. The isolator valve ensures that anode or grid current changes in later stages due to keying or modulation, cannot react on the master oscillator and cause a variation in frequency. Harmonic selection from the master oscillator takes place in the isolator stage, and the second stage of the master oscillator amplifier.

The master oscillator amplifier unit which comprises the 6 stages is mounted below the master oscillator box.

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The first of the 2 power amplifiers, No. 2 magnifier, incorporates 2 MT11 S.W. valves and is mounted in the bottom right hand corner of the transmitter.

The output from the No. 2 magnifier drives the final power amplifier, No. 1 magnifier employing 2 MT12 valves in parallel. This amplifier is mounted together with the aerial circuits in the top left hand compartment of the transmitter.

Modulation of the transmitter is effected by the direct current grid method, a description of which has been given in THE MARCONI REVIEW, No. 21, page 14. Briefly the method employed is to vary the grid bias of the magnifier valve in accordance with the modulating signal, while the driving voltage on the grid of the magnifier valve is kept constant in amplitude.

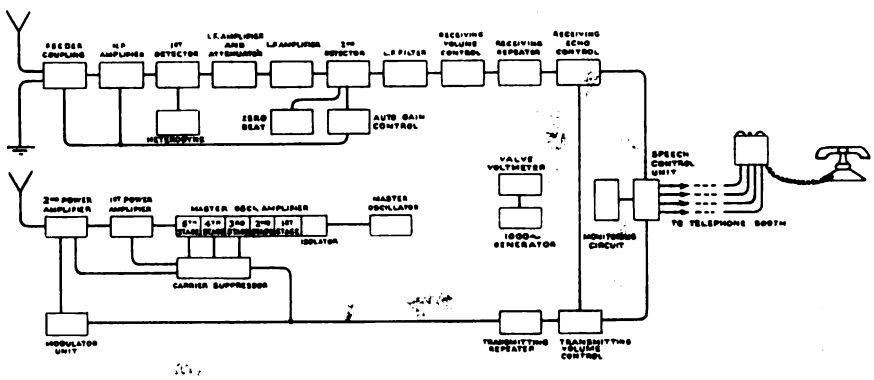

FIG. 2.

The method employed is to use the filament anode impedance of the LS5 modulator valve as a grid leak which provides an automatic bias for the magnifier. The required variations of this bias are obtained by impressing on the grid of the LS5 valve the modulating input.

The modulator panel consists of 2 LS5 valves, one as a modulating valve and the other as a Note Oscillator, which can be used for I.C.W. as a short wave telegraph transmitter. In telephony work it is not usual to key the actual transmitter, and a tone generator is therefore fitted to the ship's receiver in order that a tone may be sent to line and transmitter preparatory to passing the telephony call to the shore receiving station.

The carrier suppressor is a thermionic valve trip device, the effect of which is to so bias the grids of the No. 1 and No. 2 magnifier valves, that they take up their

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maximum dead loss load while the 3rd and 4th stages of the master oscillator amplifier are backed off, when no speech is being transmitted. Directly speech is passed to the transmitter this bias is removed and the carrier is immediately transmitted.

The transmitter is mounted on a special floating floor and sprung from the roof of the cabin to avoid vibration.

Adjacent to the Transmitter Cabin is the Machine and Battery Room.

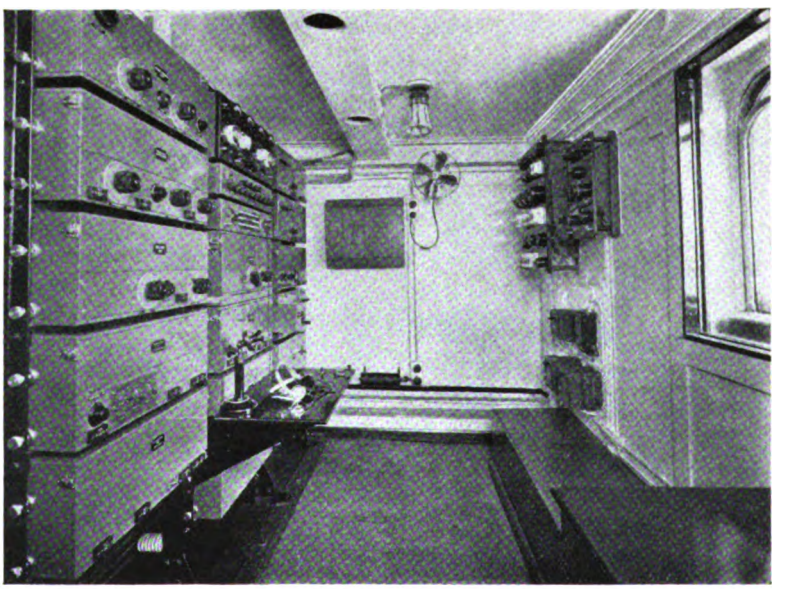

FIG. 3.

The H.T. and L.T. for the master oscillator is provided by batteries, while the H.T. and L.T. for the other circuits is provided for by machines.

In addition to telephony, provision is made for the set to be keyed as a short wave telegraph transmitter in the event of emergency, on C.W. and I.C.W.

The transmitting aerial consists of a single vertical wire 110 ft. long slung from the main aerial and brought directly to the leading-in insulator.

In addition to the aerial, an artificial load with hot wire ammeter is provided to enable the set to be tuned to the various wavelengths without being put on the air.

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The Receiver.

No special mention need be made of the receiver beyond the fact that it is housed in a special cabin on the port side of the boat deck amidships and erected in a fore and aft position on a special floating floor and sprung from the roof of the cabin to avoid vibration. The aerial for the receiver consists of a single vertical wire 100 ft. long slung from the main aerial between the centre and aft funnel and brought directly to the lead-in insulator. A di-pole aerial is also installed between the forward and centre funnel for use with the receiver when desired.

A photograph of the receiver cabin is shown in Fig. 3.

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WAVELENGTHS FOR AIRCRAFT COMMUNICATION

In connection with the equipping of aircraft—whether for military or civil purposes—with wireless apparatus of a type suitable to any particular requirements, the great importance of the correct choice of wavelengths is often not realised. The matter is accordingly one which is worthy of careful consideration, and it is with a view to assisting those responsible for drawing up specifications of performance for aircraft wireless equipment that this article has been primarily written.

BEFORE dealing with the technical aspect of this matter, it should be realised that, whereas the selection of any particular wavelength in a specified waveband is a matter which is subject only to the concurrence of the national authorities responsible for the allocation of wavelengths, the choice of the waveband itself will have to be made in accordance with the allocation agreed internationally by the Washington Radiotelegraph Convention of 1927. In this Convention, the complete ether spectrum has been divided into frequency groups (or wavebands), which have been allocated to various classes of wireless communications such as shipping, aircraft, broadcasting, point-to-point services, etc. It will be seen from this allocation that those wavebands which have been allotted to aircraft communications (which are clearly marked) embrace wavelengths varying from the ultra-short, at one end of the scale, to the long, at the other.

In this connection it should perhaps be made clear that the scope of the Washington Convention was to allocate wavebands for *international* services; national services are not necessarily subject to this allocation, but since wireless transmissions of a purely national service can be—and often are—a source of interference to similar services in neighbouring countries, and to international services, the Washington Convention clearly lays it down in Article 5 paras. 1 and 2 that: "The Administrations of the Contracting Governments may assign any frequency and any type of wave to any radioelectric station under their authority upon the sole condition that no interference with any service of another country results therefrom. These Administrations, however, agree to assign to stations which, by reason of their nature are believed to be capable of causing serious international interference, frequencies and types of waves in conformity with the rules for the distribution and use of waves as set forth below."

Technical Considerations.

Wavelengths available for wireless communications extend from one metre or less at one end of the spectrum to 30,000 metres or so at the other. No physical division of the spectrum into wavelengths of various categories can be made, but,

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by a recommendation of the meeting of the Comité Consultatif International Radioélectrique at the Hague in 1929, the spectrum was arbitrarily divided as follows :—

Ultra-short wavelengths	below 10 metres.
Short wavelengths	10—50 metres.
Intermediate wavelengths	50—200 metres.
Medium wavelengths	200—3,000 metres.
Long wavelengths	above 3,000 metres.

From the point of view of characteristics of wave propagation, however, the complete ether spectrum can be roughly divided into two groups, i.e., those wavelengths (or frequencies) at which propagation of the waves between two points on the surface of the earth occurs only along a line parallel to the surface of the earth and following the great circle path joining those points (i.e., by means of the " direct " ray), and those at which propagation occurs, in addition, by the downward reflection from an ionised layer at some height above the earth's surface (the Heaviside layer) of energy radiated from the transmitter in an upwards direction (i.e., by means of the " indirect " ray).

The first group includes both the ultra-short at one end of the scale, and the medium and long waves at the other, in the case of both of which the useful propagation normally occurs by means of the direct ray alone. In the case of the ultra-short waves (or ultra-high frequencies) the attenuation by absorption is so great that the distances over which communication can be effected, for a given radiated power, are very small ; furthermore, owing to the same reason, communication may be only possible between two points when there is an unimpeded path between these points, i.e., communication will be easiest when visual communication between the points in question would have been possible. For example, a steep hill lying in the direct path in which communication is to be effected, and under the lee of which is situated an ultra-short wave transmitter, would be liable to impede communication. For the above reasons, ultra-short wave transmitting and receiving stations for point-to-point communication should always be erected on open sites, unscreened by local objects, and preferably on high ground.

In the case of the medium and long waves, however, attenuation is relatively small, and becomes even smaller as the wavelength increases, i.e., as the frequency decreases ; the result is that, for a given power, communication can be effected over greater distances when such waves are employed than with ultra-short waves, and, furthermore, the siting of transmitting and receiving stations is not nearly so dependent upon local considerations as when ultra-short waves are employed.

The second group, in which propagation is not only effected by means of the " direct " ray but also by means of the " indirect " or reflected ray, includes the

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short, and under certain conditions, the intermediate and shortest of the medium waves.

With waves of this type, the frequencies are still relatively high, and attenuation, by absorption, of the " direct " ray—as in the case of the ultra-short waves—also very pronounced, the shorter the wavelength, the greater being the attenuation experienced. On the other hand, on these wavelengths certain of the energy radiated from the transmitter in an upwards direction travels, as mentioned earlier on, with barely appreciable attenuation, to the Heaviside layer, where it is reflected (or more correctly, refracted) in a downwards direction again so that it strikes the surface of the earth at a distance from the point of origin. The laws governing propagation by means of the " indirect " ray have been carefully investigated during the past five or ten years, and an enormous amount of observational work carried out and data collected and collated on this subject ; while it is outside the scope of this article to deal at any length with these laws, it can be stated that the distance from the transmitter at which the " indirect " or reflected ray may be expected to strike the earth's surface again depends primarily upon (A) the wavelength (i.e., frequency) employed, and (B) the nature of the great circle path under consideration, i.e., whether it is all daylight, all darkness, or part daylight and part darkness. Provided therefore, that the necessary conditions have been complied with for the distance separating the two points over which it is desired to maintain communication by means of the " indirect " ray, such communication can be effected with a transmitter of extremely low power, since, as stated above, the radiated energy in its travel to the Heaviside layer and back to the earth's surface suffers almost inappreciable attenuation.

It will be realised, therefore, from the above, that when waves of this type are employed, energy radiated along the earth's surface will quickly be dissipated by absorption, and the range of the " direct " ray will be small for a given power transmitter ; on the other hand, energy radiated in an upwards direction will be reflected back to the earth's surface again at a distance from the transmitter which may vary from about a hundred to many thousand miles, according to certain well defined laws, and the range, therefore, of the " indirect " ray can be extremely great for a given power (and hence a given weight) of the transmitter. After the (limited) range of the " direct " ray is reached, a silent zone is encountered, and this may, of course, extend for hundreds or even thousands of miles, until a point is reached where the " indirect " ray reaches the earth's surface and reception is again possible. This phenomenon is known as " skip " effect, and the distance between the useful limit of the " direct " ray and the point where the " indirect " ray strikes the earth's surface is known as the " skip " distance ; reception within the " skip " zone is, of course, not possible, apart from weak signals which may be received due to scattered radiation from the Heaviside layer.

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It must, of course, be realised that, in the same way as no clearly defined physical division of the ether spectrum into the various groups of waves or frequencies is possible, so the properties possessed by the various groups arbitrarily selected are not clearly defined, but merge one into the other. As wavelength increases from ultra-short to short and thence to intermediate, medium, and long, so the range of the " direct " ray gradually increases for a given power, and the " skip " distance decreases gradually from infinity, in the case of the ultra-short waves to zero in the case of the longer of the intermediate and the long waves ; this transition of characteristics is shown in the figures given below, which although roughly correct, vary according to the season and to the position of the great circle route with respect to the polar regions.

Wave (metres)	Skip Distance Day (Miles)	Skip Distance Night (Miles)	
		Summer	Winter
15	900	5,000	Infinity
20	600	1,400	Infinity
30	300	700	4,000
40	250	350	1,500
60	*200	250	350
80	No Skip	*250	*200
100	No Skip	*250	*200

* Very variable.

With the longer of the intermediate waves and the shorter of the medium waves, particularly at night, the " indirect " ray reaches the earth's surface, at distances within the effect of the " direct " ray, and interference between the two is experienced ; owing to the variable nature of the " skip " effect under these conditions, and to the relatively weak strength of the " direct " ray at the distances in question, the interference experienced takes the form of a periodic increase and decrease of strength of received signal. This change in strength of signal sometimes occurs with great rapidity and sometimes only gradually, and the phenomenon is known as " fading."

In addition to the above considerations, there are others of almost equal importance which have to be considered when selecting the most suitable wavelength for any specific requirement. For example, the reception of intermediate, short, and ultra-short wavelengths in the air presents greater difficulties than is the case with medium and long wavelengths, owing to the fact that, on these wavelengths, interference from the aircraft engine ignition system can be extremely serious ; this obstacle is, however, not insuperable, since it can be overcome by carefully screening the ignition system and paying the greatest attention to ensure that every metallic

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portion of the aircraft is well and truly "bonded" together. The shorter the wavelength employed, the more complete must be the screening of the ignition system, and the greater the care with which the bonding must be carried out ; on the lower of the short wavelengths, not only is it necessary to screen the magneto distributors, all high and low tension leads, and all low tension switches, but the plugs themselves must be of the screened type. Reception of ultra-short wavelengths in the air is an extremely difficult matter.

While there is no difficulty from a technical point of view in so preparing the ignition system and the bonding of an aircraft, there are objections to this procedure on account of the cost of this additional work on the aircraft, the additional weight of the screened ignition system as compared with the unscreened system, and the necessity for extremely careful maintenance in order to prevent the occurrence of possible faults in the ignition system, with the consequent risk of engine failure ; on the other hand, if, from other considerations, it appears imperative to employ short wave reception in the aircraft, then the above objections are obviously outweighed by these considerations, and, provided maintenance is carried out systematically and thoroughly, entirely satisfactory results will be obtained.

Another point which must be borne in mind when selecting the type of wavelength to be employed is the necessity or otherwise for directional reception in the aircraft ; up to the present, directional reception in the air has not been found practicable below about 300 metres, with the result that, should this form of reception be essential as an aid to the navigation of the aircraft, the choice of wavelengths is limited to those in the medium, and long wavebands.

Selection of Wavelengths—Normal Practice.

Having studied at some length the technical considerations governing the choice of wavelengths, it will be of interest to observe the effect which these considerations have had upon the normally accepted practice for various classes of military and civil aircraft wireless services.

Military Aircraft.

Dealing firstly with aircraft for military purposes, these can be classified roughly as follows :—

(A) Fighter or Interceptor Aircraft.
(B) Army Co-operation Aircraft.
(C) Short distance Reconnaissance (either military or naval) or bombing aircraft.
(D) Long distance reconnaissance or bombing aircraft.

For fighter or interceptor aircraft, short range inter-aircraft communication is required, with relatively short range ground-to-air and air-to-ground communication ; since these aircraft are always single-seaters, the pilot being the sole occupant

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of the aircraft, the use of radio-telephony is essential. Owing to the fact also that the use of trailing aerials is precluded, on account of the necessity for aerobatics to be performed, a fixed type of aerial (which, owing to its small physical dimensions and capacity, is efficient on short and intermediate wavelengths alone) is also essential ; for these reasons, therefore, intermediate wavelengths are normally employed for these aircraft, the wavelengths chosen being usually of the order of 70—130 metres ; wavelengths below about 70 metres are not usually employed on account of the increased ignition interference experienced, while on those above about 130 metres it is difficult to instal an efficient fixed aerial on the small aircraft normally employed for the work.

For army co-operation aircraft, medium range ground-to-air and air-to-ground communication is required. Since the aircraft are normally two-seaters, telegraphy is usually the means of communication employed, the observer as a rule acting as W/T operator ; in certain cases, such as when communicating with infantry or tanks, telephony may be used, but when communicating with artillery for ranging or other purposes, telegraphy is almost always employed. Ranges up to 20 miles may be necessary, and the use of a fixed aerial, although preferable from the point of view of aerobatics is not essential ; in most countries, however, a short trailing aerial is preferred. Owing to the difficulties of reception on short wavelengths in the air, and to the limited range of the " direct " ray on these wavelengths, the use of intermediate and medium wavelengths, of the order of 150—400 metres, is normal practice for this type of aircraft.

For short distance reconnaissance or bombing aircraft (including fleet spotting aircraft) continuous communication between aircraft and the base is necessary up to a maximum distance of some 100 miles or more ; furthermore, it may often be advantageous to provide the pilots of such aircraft with navigational assistance in the form of direction finding, either by means of a direction finder carried in the aircraft and taking bearings on transmissions from known ground stations, or by means of direction finders on the ground taking bearings on transmissions from the aircraft. Since such aircraft are usually two or three-seaters of medium size, the wireless equipment is not so limited by considerations of space and weight as in the case of smaller aircraft ; in addition, the crew can usually include a trained W/T operator, with the result that telegraphic communication can be—and, in practice, is almost always—employed. From the above considerations, therefore, medium wave sets of medium power are almost universally employed for such aircraft, wavelengths of the order of from 500 to 2,000 metres being normally utilised.

For long distance reconnaissance or bombing aircraft (both day and night) the same considerations apply as in the case of the short distance reconnaissance or

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bombing aircraft, with the exception that, not only are the distances, over which continuous communication with the base is necessary, much greater (often being of the order of 300 miles or more) but, in addition, the aircraft are usually so large—particularly in the case of bombers—that the carriage of a more powerful medium wave set is possible than is the case with the short distance reconnaissance or bombing aircraft. Furthermore, it may occur that flights of such aircraft, being obviously subject to military considerations alone insofar as objectives are concerned, may necessitate the aircraft being out of touch with the base, even though a relatively powerful medium wave set is carried. For this reason an additional short wave set of relatively small power is often carried in such aircraft as an auxiliary means of communication at extreme ranges ; by judicious selection of the wavelengths used, so as to avoid " skip " effect, most satisfactory results may be attained with such auxiliary equipment.

Civil Aircraft.

Dealing now with civil aircraft, these can be roughly divided into three groups :—

(A) Light aeroplanes.

(B) Passenger (or freight) carrying aircraft employed on regular services over established air routes.

(C) Passenger (or freight) carrying aircraft employed on regular services over country where an air route organisation has been only partially established, or over long sea routes.

With regard to light aeroplanes, the development of this form of flying has mostly been along sporting and social lines ; training of pilots has also been to a great extent carried out with this type of aircraft. Up to the present, the necessity for the carriage of wireless apparatus has not been experienced, except in isolated cases such as foreign touring, special flights, etc., but it appears likely that a scheme may shortly be evolved in Great Britain whereby weather reports are broadcast by radiotelephony from various centres in accordance with a carefully organised routine, in order that pilots carrying out cross country flights may receive such reports in the air and hence be better advised of the weather conditions ahead of them than is possible at present. A maximum ground-to-air telephony range of about 80—100 miles is likely to be required, and naturally, it is of prime importance that the receiving equipment in the aircraft shall be not only as light and compact, but that it shall also be as cheap as possible ; furthermore, the use of a trailing aerial is to be deprecated if it can be avoided, on the score of the difficulty of accommodating the aerial winch and fairlead in the extremely small space available in aircraft of this type, and also because of the potential danger should pilots forget to wind in their aerials when flying low or on the point of landing.

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Up to the present, the most suitable wavelength for such a wireless service has not been decided, but in view of the above considerations, the majority of opinion favours the use of a wavelength between 100 and 200 metres, since on these wavelengths an efficient fixed aerial can be designed for most modern light aeroplanes, and since, for other technical reasons, such a wavelength appears entirely suitable.

For those light aeroplanes and " taxi " aircraft which often fly along recognised air routes, the requirements to be met are, in the main, similar to those which arise in the case of normal passenger (or freight) carrying aircraft operating over established air routes, and are dealt with under that heading.

In the case of passenger (or freight) carrying aircraft employed on regular services over established air routes, the selection of wavelength is obviously dependent upon the ground wireless stations which have been erected by the various Governments concerned along that route, and with which communication will have to be carried out. Since established air routes are (in Europe, at any rate), usually international rather than national in character, the ground organisation, including wireless services, is internationally regulated ; a band of wavelengths from 850 to 950 metres was accordingly allotted for this purpose by the Washington Radiotelegraph Convention of 1927, and in this band the wavelength of 900 metres has been accepted in most countries in the world as an international civil aircraft wave, in the same manner as the wavelength of 600 metres has been accepted internationally for shipping. In addition, wavelengths of 870 and 930 metres have been accepted in a number of countries as alternative wavelengths for telegraphic and telephonic communication respectively, for use when the 900 metre wave is congested. Bands in other parts of the ether spectrum were also reserved at Washington for aircraft communications, but no single wavelength other than that of 900 metres was definitely allocated for international civil aviation work.

In air routes of this type, ground stations are usually not more than 300 miles apart, owing mainly to the fact that aerodromes are necessary at this distance from one another on account of the average endurance of aircraft employed on passenger carrying work. Furthermore, owing to the facts that (A) the most direct communication between the *pilot* of such aircraft and the ground is often essential, and (B) the payload of the aircraft being strictly limited by Certificate of Airworthiness conditions, the carriage of a trained telegraph operator involves the loss of a paying passenger, with consequent financial loss, and it may often be preferred to utilise a pilot-operated telephony service rather than an operator-operated telegraphy service. In addition, the necessity for maintaining regular services under all conditions of weather often renders it extremely important that navigational aid by means of directional wireless systems should be available for the pilot of the aircraft ; as mentioned earlier on in this article, directional wireless systems available in

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practice—with a few solitary exceptions which are only in the experimental stage at present—operate solely on wavelengths above approximately 300 metres.

From a technical point of view, therefore, apart from questions of international regulations, the use of medium or long wavelengths for this class of work is, from all points of view, to be recommended, except possibly that of the range-for-power ratio (and hence range-for-weight ratio) of the transmitting apparatus, which is considerably higher when short wavelengths are employed than with medium or long wavelengths. From the practical point of view, however, the question of wavelength has already been settled internationally, and aircraft operating companies will naturally prefer to communicate with ground stations already erected by Government authorities, rather than erect such stations at their own expense—even if such latter course were permitted by the authorities concerned, which is definitely not the case in most countries.

For passenger (or freight) carrying aircraft employed on regular services over country where an air route organisation has been only partly established, i.e., where ground facilities are few and far between, and also where such aircraft are operating over long sea routes, it may often be necessary to consider the use of short wavelengths either in place of, or in addition to, medium or long wavelengths, on account of the higher range-for-power ratio obtained on such wavelengths.

In the case of land aircraft following a sparsely organised route, short wavelengths are often employed as the sole means of communication, and provided the actual wavelength to be employed is carefully selected to suit the particular conditions obtaining along the route, and that the aircraft ignition system is fully screened, excellent results can be—and in fact have often been—obtained. Owing to various technical considerations, the use of telephony on these short wavelengths has not been found to be satisfactory over any but very short distances (i.e., within the range of the " direct " ray) unless a transmitter employing a quartz crystal type of frequency control is used to maintain the frequency (or wavelength) steady to within extremely fine limits. As a transmitter of such design is relatively bulky and heavy for a given radiated power, the use of short wavelengths as described above is confined almost entirely to telegraphic communication, and a trained operator is, of course, carried in the aircraft.

In the case of large seaplanes or flying boats operating over long distance oversea routes, communication can often be carried out with coastal or ship stations within range along the route, and such stations employ, in the majority of cases, medium wave apparatus operating on the international shipping wave of 600 metres. For this reason the carriage of medium wave apparatus is essential, particularly since an aircraft direction finder can be employed with advantage in obtaining navigational aid from these stations—a matter which is often of the greatest importance when

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flying long distances over sea and out of sight of land, and when depending almost entirely on dead reckoning methods of navigation.

If communication with marine air ports or bases at extreme ranges is considered necessary, however, the carriage of supplementary short wave apparatus is essential, since the use of medium wave apparatus of sufficient power to communicate over such ranges is often impracticable from the points of view of weight, size and cost. Hence, for aircraft of this type, both medium and short wavelengths are normally employed, the apparatus being capable of functioning on 900 and 600 metres on the medium waves, and on any selected short wavelength or wavelengths.

In an article of this nature it is obviously extremely difficult to do more than touch on the many aspects of a complex subject such as that of the choice of suitable wavelengths for various classes of aircraft ; it is to be hoped, however, that the information given above will serve as a rough guide to those responsible for specifying the type of wireless apparatus to be installed in such aircraft, and the opportunity is here taken to state that detailed information or advice will gladly be given at all times by the Marconi Company, both on this and other kindred subjects.

C. B. CARR.

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THE VERTICAL POLAR DIAGRAM OF A MARCONI BEAM AERIAL

The calculation of the vertical polar diagrams of aerial arrays presents many more difficulties than does the corresponding calculation in the case of horizontal polar diagrams.

A method of calculation based on the analysis given in a paper entitled "Short Wave Wireless Telegraphy," Proc. I.E.E., Vol. 65, No. 366, June, 1927, is described in the following article.

THE horizontal distribution of energy transmitted from an array of aerials such as a Marconi Beam is now well known.

Measurements of the distribution of field strength taken at a distance of 10 wavelengths or so agree fairly well with the values calculated on the assumption that the currents in all the aerials of the array are equal and in phase.

So far it has not been possible to measure the energy distribution in the vertical plane, and any attempt to make such a measurement must be attended with very considerable practical difficulties.

There remains only the method of calculation of the vertical polar diagram. So far as the writer is aware, this has not yet been attempted. The calculation is one of considerably greater difficulty than that required for the horizontal plane and the reason for this lies in the uncertainty introduced by the finite conductivity of the earth. It is obvious in the first place that the earth's conductivity does not affect the *distribution* of energy in the horizontal plane, for each aerial of the array produces the same field strength at a given distance and the distribution of energy in the horizontal plane only depends on the relative phases of the fields produced (assuming all the currents equal), which do not depend on the earth's conductivity. If, however, the absolute strength of the field in terms of the aerial current is required, the effect of the earth's conductivity must be taken into account.

With regard to the distribution of energy in the vertical plane, the finite conductivity of the earth has a profound effect. Perhaps the easiest way to realise this is to consider the radiation produced by an element of current at a considerable height h above the earth's surface (Fig. 1).

At a great distance r energy arrives by the direct ray r_1 also by the reflected ray r_2. If the earth were perfectly conducting there would be perfect reflection at R and the total field at the receiver would be the sum of the field due to $i\,ds$ and that of its image at a depth h below the surface, due account being taken of the difference of phase $\left(\frac{4\pi h}{\lambda}\sin\theta\right)$ of the two fields. If, however, the earth is assumed to have a finite conductivity the amplitude of the reflected ray is less and its phase different.

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The method of calculation of the vertical polar diagram consists in taking account of the sum of the elements of field strength due to the direct and reflected waves from the earth's surface.

The calculation is based on the analysis first given by the writer in Proc. I.E.E., "Short Wave Wireless Telegraphy," Vol. 65, No. 366, June, 1927, where it is shown that an extension of Sommerfeld's analysis* of the transmission of electric waves over the earth's surface may be made to yield the vertical polar diagram of a small aerial situated at any height h above the earth's surface. This analysis has recently been confirmed by the theoretical work of M. J. O. Strutt† and by W. Howard Wise‡.

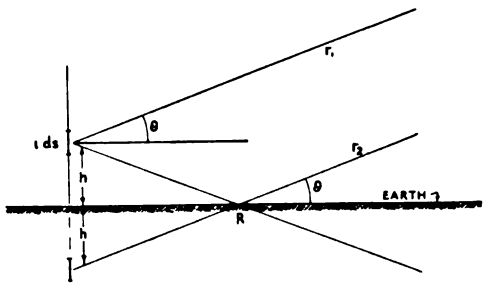

FIG. 1.

It is shown that the field due to an element $i\,dh$ at a height h above the earth's surface is proportional to the quantity

$$\cos\theta\, i\, dh \left\{ e^{-i\varphi} + \left(\frac{n\alpha - n'}{n\alpha + n'}\right) e^{+i\varphi} \right\}$$

$\varphi = \frac{2\pi h}{\lambda} \sin\theta$, and θ is the angle of elevation of the ray.

$$n = \sin\theta$$

α and n' depend on the earth constants in the following way :—

$$\alpha = \varepsilon + 2i\sigma\lambda C$$

$$n' = \sqrt{\sin^2\theta + \varepsilon - 1 + 2i\sigma\lambda C}$$

σ = conductivity of the earth is C G S Em. units.

ε = specific inductivity of earth.

λ = wavelength in cms.

C = velocity of light = 3×10^{10} cms./sec.

The quantity $\frac{n\alpha - n'}{n\alpha + n'}$ is the reflection coefficient of the earth for vertically polarised wave with angle of incidence $90° - \theta$.

In C. S. Franklin's uniform aerial the effective current in the aerial is nearly a constant. In this calculation the effective radiating current is assumed as constant, in which case the total field due to an uniform aerial of height h is

$$\cos\theta \int_0^h \left\{ e^{-i\varphi} + \left(\frac{n\alpha - n'}{n\alpha + n'}\right) e^{+i\varphi} \right\} dh$$

* Annalen der Physik 1909, ser. 4, Vol. 28, p. 665.
† Annalen der Physik 1929, 5 Folge, Band 1, Heft 6.
‡ "Bell Journal," Oct. 1929, Vol. 8, No. 4.

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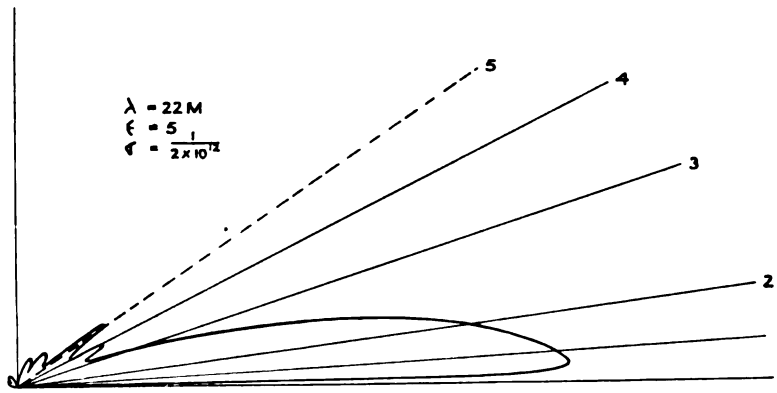
and since n, α, and n' do not contain h, this reduces to

$$\frac{1}{i \tan\theta \, 2\pi}\left[\left(1 - \frac{n\alpha - n'}{n\alpha + n'}\right) - \left(e^{-i\varphi h} - \frac{n\alpha - n'}{n\alpha + n'} e^{+i\varphi h}\right)\right]$$

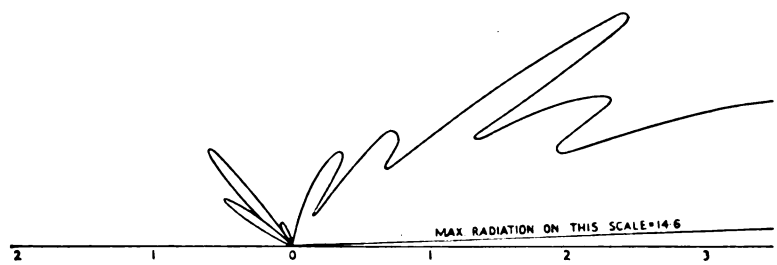
where

$$\varphi h = \frac{2\pi h \sin\theta}{\lambda}$$

The polar diagram of the simple uniform aerial of height can be calculated from this.



CURVE 1.



CURVE 2.

FIG. 2.

The polar diagram in a vertical plane perpendicular to the plane of the array of a beam aerial will then be the same. If we wish to take account of a reflector spaced a distance a quarter of a wavelength from the aerial and with currents differing in phase by $\pi/2$ we have to multiply by the factor $\{1 - \cos[\pi/2 (1 + \cos\theta)]\}$ to get the final result of the radiation in a vertical plane of a beam aerial of height h. Some care must be taken in choosing a typical example as the computation is very laborious.

A wavelength of 22 m. was taken since the facsimile results have given evidence of a set of rays propagated on this wavelength over the transatlantic route. The angles of these rays are known and the relative energies emitted along each of these rays can be calculated when the polar diagram is known.

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The value of σ the earth's conductivity was taken as $\frac{1}{2 \times 10^{12}}$ which is the value obtained at Broomfield for damp earth in the earth screen resistance measurements.

Somewhat lower values of this quantity are obtained from the results of the attenuation of broadcast waves by applying Sommerfeld's transmission theory, but as these probably include some dielectric losses in trees and vegetation the higher value $\frac{1}{2 \times 10^{12}}$ was chosen as representing the true earth's conductivity.

A value of $\varepsilon = 5$ was chosen, when the value of the conductivity is so high the choice of ε between fairly wide limits makes only little difference.

The height of the aerial was taken as three wavelengths (66 m.) in this case, and the final results are shown on curves 1 and 2. Perhaps the most striking result is the extraordinary concentration of energy in the lower angle directions. The maximum radiation occurs at only 2° elevation and practically the whole of the energy is radiated below 20°. In one respect the results may appear contradictory.

The diagram shows zero radiation along the horizontal direction. This is not meant to imply that no radiation is projected horizontally, but that at great enough distances the radiation projected horizontally is negligible compared with the radiation at a finite angle. This absence of horizontal radiation is a consequence of the high attenuation of the horizontal rays which are rapidly reduced by the earth's resistivity. This absence of horizontal radiation is a characteristic of all short wave aerials (examples are given in the curves published by M. J. O. Strutt and Howard Wise).

On this wavelength the direction of the useful rays for transatlantic transmission is given by the five lines labelled 1, 2, 3, 4, 5. The ray 5 is the upper limit of useful radiation, that is to say, energy transmitted at higher angles than this, will, in all but exceptional cases, penetrate the Heaviside layer and escape. It will be seen that the energy transmitted on the higher angle rays 3 and 4 is in general, small compared with that emitted on rays 1 and 2.

As far as the back radiation is concerned the main loops are at 35° and 50°, and the maximum amplitude ratio is only $\frac{1}{142}$. In general the direction of the lowest loop is above the cone of useful radiation. This may account for the fact that practically no echo is ever heard on WAJ a 22m station at New York. If, however, the aerial were tilted back some 15° as in some recent experiments, the lowest back angle loop might come within the cone of useful radiation and echo might occur under suitable transmission conditions.

T. L. ECKERSLEY.

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MARCONI NEWS AND NOTES

ULTRA SHORT WAVE WIRELESS TELEPHONY

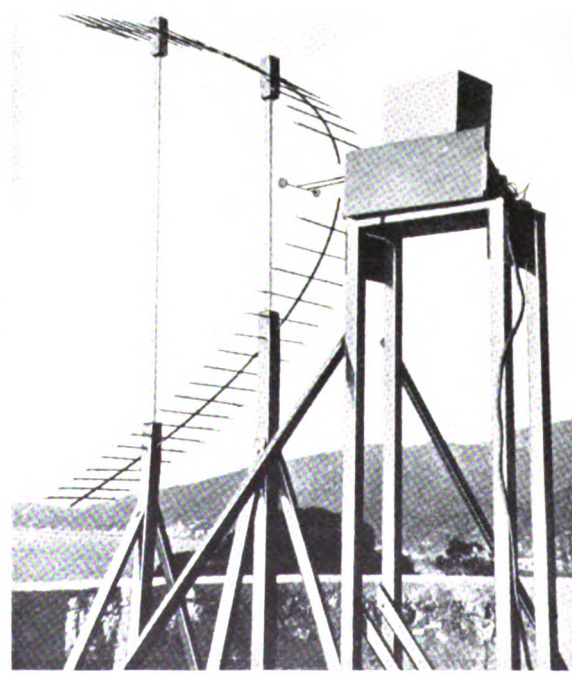
IN the presence of representatives of the Italian Government, an official demonstration took place on November 19th in Italy, between Santa Margherita Ligure and Levanto—a distance of 25 miles—of the new Marconi quasi-optical, ultra-short wave radio-telephone system. The wavelength used was only 50 centimetres (the same as that employed in the previous demonstration carried out between Santa Margherita Ligure and Sestri Levante over a distance of 11 miles), corresponding to the enormous frequency of six hundred million cycles per second.

The success of the demonstration was all the more complete because, although the range had been increased from 11 to 25 miles, the margin in the signal strength was such as clearly to indicate to all present that the apparatus used was capable of covering a considerably greater distance.

Early Experiments with Ultra-Short Waves.

In an interview granted immediately after the demonstration to representatives of the Press, His Excellency the Marchese Marconi made the following interesting statement :—

" Since 1896, when I was already experimenting with wavelengths of 20 centimetres, I had no doubt in my mind but that the short waves, which are called quasi-optical because they behave very much like the waves of visible light, would one day come into use for commercial communications. The results of those very early tests were confirmed by the more recent experiments I carried out at Leghorn during the world-war using a wavelength of 50 centimetres. However, nobody, myself included, had then succeeded in producing ultra short wave apparatus sufficiently powerful, economical and reliable to justify its immediate use for public telephone or telegraph services over suitable distances.



Marconi quasi-optical ultra-short wave transmitter.

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Public Telephone Services in Italy.

"During the last six months, my assistants, particularly Mr. G. A. Mathieu, and myself have been concentrating our efforts towards a commercial solution of the problem, and many unexpected and valuable discoveries have been made. I would, therefore, ask you not to consider this demonstration as a mere scientific experiment, but as a test of a new practical and commercial radio-system which will very shortly be used for public services in Italy. Owing to its simplicity the new system is very moderate in price and in running costs: it will thus soon afford to the inhabitants of many small islands scattered in the Mediterranean a reliable telephone service which they could not, heretofore, enjoy in consequence of the high cost of the submarine cable telephone installation."

Requested to state whether it was correct that the application of this "quasi-optical" wave was strictly limited to very short distance communications, Marchese Marconi added: "Well, at the present stage of our knowledge I do not anticipate a reliable range of more than about 100 miles; but this is, of course, a very useful range in itself, and could be very greatly increased by making use of relays or repeaters wherever possible."

Wireless and Night Flying.

WIRELESS direction finding, which enables pilots to be informed of their position in the air during foggy or cloudy weather, is one of the most valuable services of wireless to aviation. By its aid, a number of flights have been made between London and the Continent, during which the pilots have scarcely been able to see the ground throughout the journey, but, reliable as it has proved under these conditions, wireless direction finding has hitherto been subject to one limitation. It was subject to errors during the hours of darkness, and particularly at sunset and sunrise, due to the natural phenomenon of the irregular polarisation of wireless waves at these times.

Realising the importance of providing a direction finder capable of giving accurate bearings at all times of the day and night, particularly in view of the probable extension of night flying services in the near future, the Marconi Company has now developed a direction finder to overcome this "night effect."

Exhaustive tests have demonstrated that this apparatus, known as the Marconi-Adcock direction finder, is as reliable during the most critical periods of "night effect" as is the well-known Bellini-Tosi apparatus under normal conditions.

The first station of this type to be erected has been built by the Marconi Company for the Air Ministry direction finding station at Pulham, Norfolk, which,

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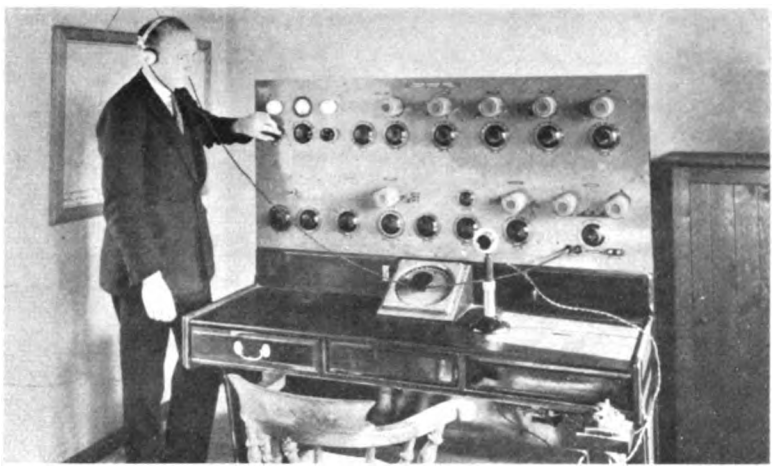
in conjunction with the wireless direction finding station at the London Air Port, Croydon, operates the direction and position finding service for aircraft on the London-Continental air routes.



Marconi-Adcock Direction Finder at Pulham.

During a night flight specially arranged by the Air Ministry, fourteen observations were made by an aircraft transmitting signals from known positions so that a check could be kept. The distance in every case was in the neighbourhood of 100 miles, and the accuracy of the new direction finder was complete, although the ordinary system of wireless direction finding was, at the time, most unreliable even over much shorter distances owing to "night effect."

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THE MARCONI REVIEW

March-April, 1932

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ENGINEERING

THE MARCONI REVIEW

No. 35. *March-April, 1932*

Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.

THE NEW HIGH POWER BROADCAST STATION AT BEROMUNSTER, CANTON LUCERNE

The new transmitter for the Swiss Telegraph and Telephone Administration installed by the Marconi's Wireless Telegraph Company possesses the following characteristics :—

It is capable of introducing into the aerial system unmodulated energy of 60 kw. and of transmitting on any wavelength between the limits of 300 and 600 metres (1,000/500 kcs.).

The frequency constancy of the carrier wave is maintained by the employment of a Marconi valve master oscillator.

The modulation is deep and free from distortion over a range of frequencies between 30 and 10,000 cycles.

The transmitter is of the latest type and possesses many new and novel features, which are briefly described in the following article.

General Description of Equipment.

A GENERAL view of the broadcast station is shown in Fig. 1 and its geographical position in Fig. 2.

The system of modulation employed is that generally termed low power modulation, that is, modulation is introduced into one of the low power stages and the modulated high frequency energy obtainable from this stage is amplified by subsequent stages.

This system of amplification of modulated high frequency possesses certain advantages amongst which are the possibility of increasing at some future time the power radiated by the addition of further stages of amplification or alternatively by the employment of still larger power valves in the final amplification stage.

The transmitter comprises the following principal parts :—

Constant Frequency Valve Drive.
Modulated Amplifier.
Intermediate Amplifier.

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Power Amplifier.
Main Closed Oscillatory Circuit.
Coupling and Aerial Tuning Units.
Control Desk.

In Fig. 3 is shown the arrangement of the various units each of which is enclosed within a highly polished aluminium and glass case.

The novel method of mounting the units on a raised platform has a pleasing effect and safeguards visitors from coming into contact with parts of the equipment which are of necessity at a high electrical potential during the periods of transmission and moreover has the advantages of providing space under the panels for the accommodation of water pipes, cables and conductors.

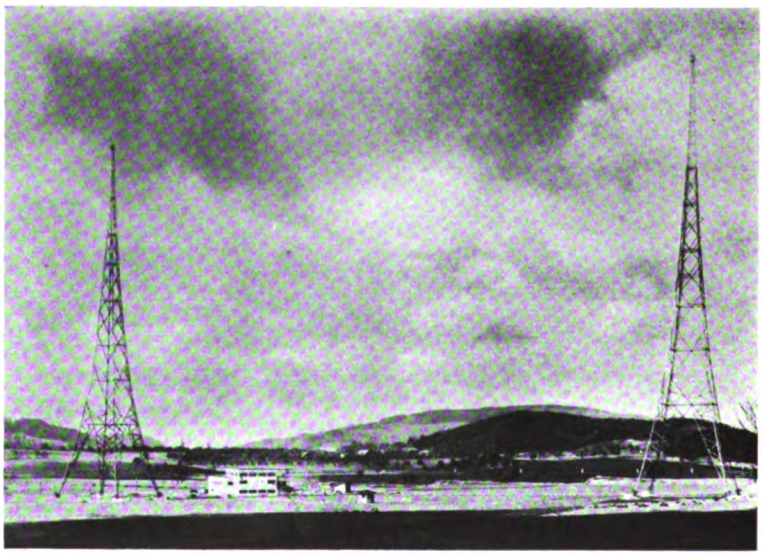

FIG. 1.

Mercury Power Rectifier.

This represents one of the most recent developments in rectifier design, although mercury arc rectifiers have been in use for many years for electric railway and tramway systems.

It has only been rendered possible to employ this system of rectification for extra high voltage by the enterprise of the Marconi Company working in conjunction with the Swiss Brown Boveri Company.

The first high voltage mercury arc rectifier of this type was installed in the high power radio station at Warsaw, Poland. The splendid results there obtained and since improved upon have fully justified the Swiss Telegraph Administration

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in adopting this system of rectification for their principal broadcast station. To an engineer the robust all-metal construction makes a peculiar appeal and to the electrical engineer the high efficiency obtainable (about 95 per cent.) a truly remarkable achievement.

In Fig. 4 it will be seen that the claim for robustness is justified.

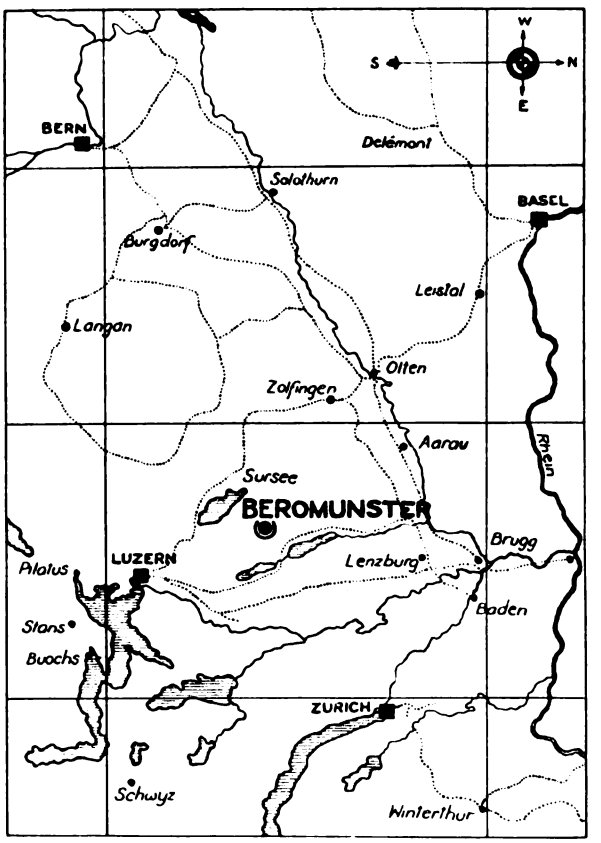

FIG. 2.

The principle of operation is as follows. The three phase current as obtained from the supply terminals is passed through a voltage regulating transformer, then through the main power transformer to the six phase mercury arc rectifier.

The rectified current thus obtained is then passed through a smoothing or filter circuit to reduce the ripple voltage to a value within .05 per cent.

The electrical characteristics of the rectifier are :—

Input supply : 11,500 volts, 3 phase 50 cycles.

Output voltage regulation at any voltage between 5,000 and 12,000 volts.

The full load 270 kw. at 12,000 volts 22.5 amps.

Fig. 5 shows the mercury arc rectifier circuits in schematic form.

The operation of the mercury arc rectifiers depends on the valve action of a metallic arc in a vacuum. The rectifying action is due to the fact that between two metallic electrodes, insulated from each other and in a highly evacuated space, current can only pass if the negative electrode (the cathode) is excited, that is, made hot as a result of electronic emission.

Suitable electrodes are used, one of which is excited. The vapourised electrode material is automatically returned. Thus an apparatus is produced which, on being connected to an alternating current supply, allows current to pass in one

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direction only. The vapourised electrode material is in fluid form, the metal mercury being made use of.

The arc is struck between an auxiliary striker and the mercury cathode, and subsequently maintained between special pairs of anodes called main anodes. These anodes are supplied from their own transformer which has the neutral point connected to the cathode through an ohmic and inductive resistance.

The cathode spot now maintained at a white heat due to the resistance offered, remains, so long as a current flows from cathode to anode.

FIG. 3.

The arc is contained in a metal chamber. The insulated mercury cathode is located in the centre of the bottom of the arc chamber or cylinder.

The anode supporting plate forms the top of the arc chamber. The main anodes are spaced in a circle round this plate each having its insulated bushing. Besides these main anodes, there are two smaller excitation anodes (already referred to as maintaining the cathode hot), fed through a single phase alternating current circuit, independently of the main current.

The upper portion of the rectifier, comprising the anode plate, can be raised from the arc cylinder to enable the interior of the cylinder to be inspected. The cylinder is surrounded by a water jacket.

A pump with necessary pipes and accessories is supplied for the circulation of the cooling water, the rate of flow of which will depend on the output of the arc.

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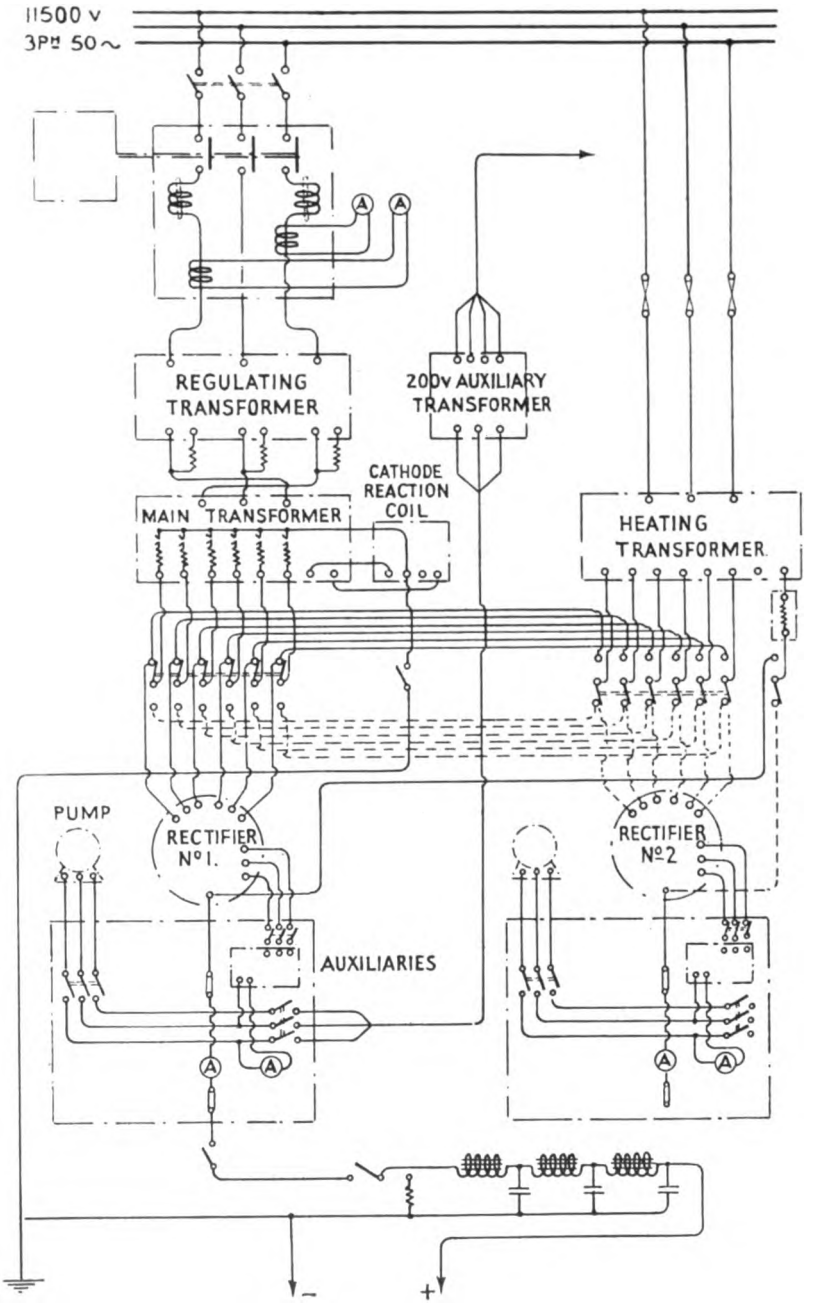

FIG. 5.

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In order to indicate the temperature of the anode plate a thermometer is placed in an aperture in the anode plate, and is visible from outside, so that the temperature can be controlled.

To maintain the vacuum inside the chamber, a mercury vapour vacuum pump is mounted directly on the anode plate, and a motor-driven auxiliary oil vacuum pump is mounted on an insulated bedplate. These pumps are automatically controlled, and the degree of vacuum is indicated by means of an electrical device.

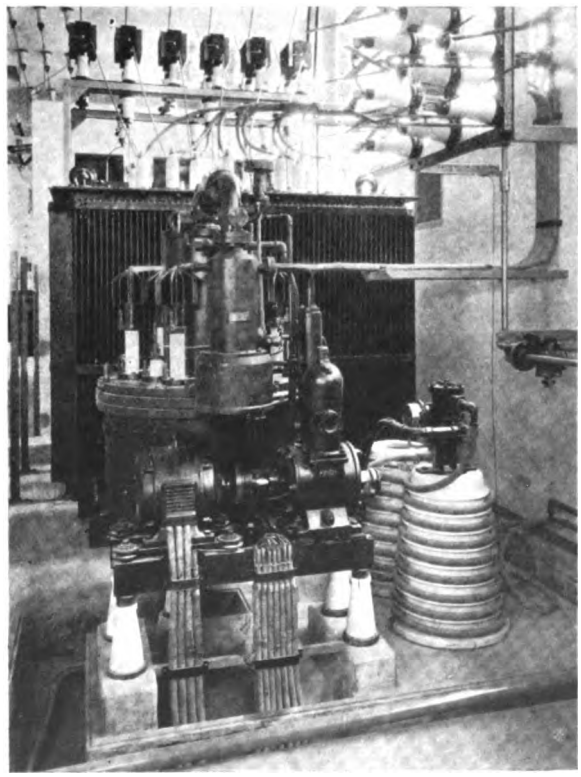

FIG. 4.

The starting up and shutting down of the rectifier is simple, and is effected by a remote control panel which closes the circuits of the starting and exciting rectifiers, thus starting up the ignition and excitation of the rectifier, at the same time starting up the water cooling system.

Control of the D.C. output volts of the rectifier is brought about by the use of a remote controlled oil immersed switch connected to numerous taps of a transformer on the primary alternating current supply to the arc. In this manner the D.C. output volts can be regulated in steps from half to full value.

Constant Frequency Master Oscillator.

The constant frequency master oscillator unit consists of an aluminium case containing the master oscillator valve with its massive tuning coils and condensers which is placed within a heat insulated chamber. The temperature within the chamber is kept constant to within narrow limits by means of an automatic thermostat and relay working in conjunction with heater lamps.

The master oscillator operates at one half the desired frequency and is used to drive the frequency doubling circuit, consisting of a screened grid valve and the necessary H.F. circuits for harmonic selection of the required stabilised frequency.

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The 1st and 2nd bridge isolator circuits comprise two cascaded stages of accurately balanced bridge amplifier circuits, so arranged that there is no back reaction to the drive.

The 2nd bridge mounts 4 Type L.S.5 valves and has sufficient output to drive the next magnifier stage.

The master oscillator circuits are energised from storage batteries.

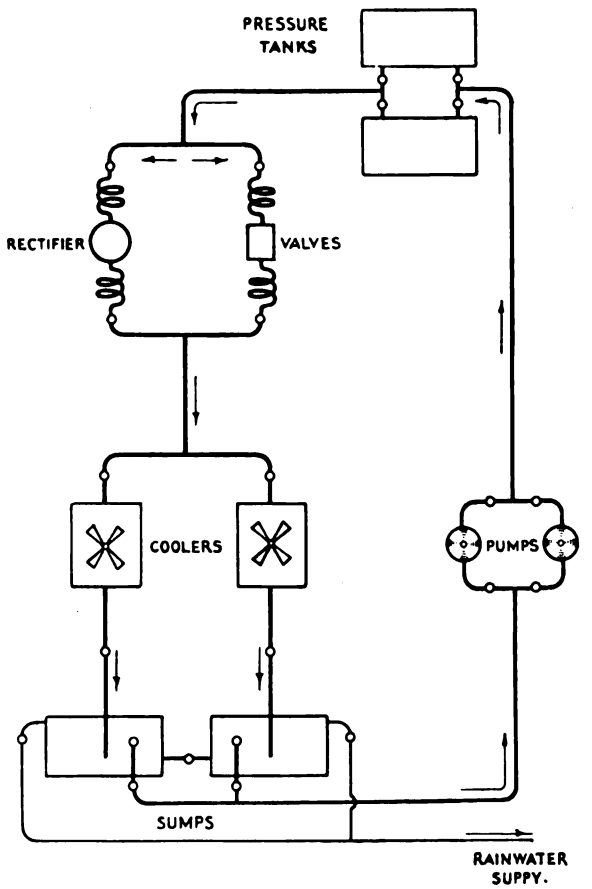

FIG. 6.

H.F. Magnifier.

The high frequency magnifier circuit consists of a Type D.E.T.2 valve completely isolated in a screening box, and complete with all necessary apparatus for high frequency magnification of the output from the master oscillator.

The filament current for the valve is taken from the D.C. 25-volt supply, the anode being fed from an H.T.-D.C. motor generator which also supplies the anode voltage for the next stage. The H.F. magnifier stage is inductively coupled to the succeeding isolator stage by means of a variable coupling.

Isolator Stage.

The isolator consists of one Type D.E.M.2 valve mounted in a screened case, complete with H.F. inductances, condensers and necessary indicating instruments. The filament current is supplied from the main filament lighting machine.

The circuit is neutralised and the valve is provided with a negative grid bias adjusted so that no grid current flows. This is in order that the load on the drive shall remain constant and completely free from any inter-actions from the subsequent modulated stages.

The isolator is directly coupled to the succeeding stage (modulated amplifier) by means of a variable connection on the anode tuning inductance.

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Modulated Amplifier.

The modulated amplifier consists of one Type D.E.T.3 valve mounted in a screened case, complete with H.F. inductances, condensers and necessary indicating instruments. The anode voltage is taken from the 3,000 D.C. supply, and the filament current is supplied from the main filament lighting machine. The circuit is neutralised and the anode supply is connected through an iron core choke coil for purposes of modulation.

The modulated amplifier is inductively coupled to the succeeding stage (intermediate amplifier) by variable coupling coils tuned by a variable condenser.

Modulator and Sub Modulator.

The modulator and sub-modulator consists of one Type M.T.9l valve and one Type D.E.T.2 valve mounted in a screened case, complete with coupling resistances, condensers and necessary indicating instruments. Both valves are fed from the H.T.-D.C. machine. The current for the filaments of the modulator (M.T.9l) and the sub-modulator (D.E.T.2) is supplied from the main filament lighting machine.

The modulator is resistance-capacity coupled to the sub-modulator, and the latter is arranged for transformer coupling to the final stage speech amplifier. The design of this stage is such that full modulation of the modulated amplifier is obtainable before grid current is reached in the modulator.

Spare Valve Holders.

Spare valve holders are provided so that in the event of a failure a reserve valve can be switched into circuit.

Intermediate Amplifier Unit.

The intermediate amplifier consists of two water-cooled valves mounted in a screened aluminium framework, complete with H.F. inductances, condensers, water-cooling apparatus and necessary indicating instruments. The valve filaments are heated from the main filament lighting machine, and the anode voltage is taken from the main power rectifier supply at approximately 10,000/12,000 volts. The circuit is neutralised, and a high negative grid bias is provided so that comparatively small power is required for the modulated amplifier to drive this stage.

Two spare valve holders are included so that a reserve valve can be switched into circuit on either side of the bridge balance, in case of failure of the working valve.

The intermediate amplifier is coupled to the succeeding stage (main amplifier) by variable coupling condensers and tuned by a variable inductance.

Power Amplifier Unit.

The main amplifier consists of two screened frameworks each mounting eight Type C.A.T.6 water-cooled anode valves, complete with water-cooling apparatus and necessary indicating instruments. A spare valve holder with H.T. switch is provided in each panel so that a reserve valve may be switched in circuit. The

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filament current is supplied from the main filament lighting machine and the anode voltage is taken from the main rectifier supply at approximately 11,500 volts, a motor generator being used to provide the grid bias potential. Modulation indicators are fitted to the grid and anode circuits of this amplifier.

The peak voltmeter consists of a two electrode rectifying valve connected in series with a blocking condenser across the terminals of which it is desired to measure the peak voltage. In parallel with the anode filament circuit of the rectifying valve is connected a moving coil milliammeter in series with a high resistance. The resistance is of such a value that the milliammeter can be calibrated to give an indication of the voltage across the rectifying valve and hence the peak volts across the terminals to which the apparatus is connected.

The ratio of the indications on the power amplifier anode peak voltmeter when the transmitter is unmodulated and again when being modulated thus gives an indication of the modulation of the transmitter.

High Frequency Circuits.

The main power amplifier closed oscillatory circuit comprises a copper tube inductance, two air dielectric high tension condensers and two oil dielectric tuning condensers. The whole of this portion of the equipment is completely enclosed in an aluminium case in order to secure freedom from reaction with any one of the prior circuits.

From the coupling winding is taken a pair of feeder lines which convey the modulated carrier wave energy to the aerial coupling circuits placed in the feeder house under the aerial.

The feeder lines, where they pass through the transmitting room, are shielded by encasing copper tubes.

In the feeder house are the aerial tuning inductance, condensers and coupling coil as required for tuning the aerial system to the working wavelength and coupling the feeder system to the aerial.

Control Unit.

The system of automatic central control of the broadcast transmitter has been highly developed. It has been rendered possible for the station attendant when seated at the control desk to operate, control and supervise the proper operation of the complete transmitter.

A complete range of measuring instruments is mounted on the front of the unit. These serve to provide means for correctly adjusting the principal circuits.

The lamps and audible signals indicate when the control circuits are or are not properly completed. Press buttons are fitted controlling the various automatic circuit breakers.

This unit is built of polished aluminium and takes the form of a writing desk.

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Aerial System.

The aerial system which is of the T type, is suspended from a pair of 125 metre lattice steel insulated towers placed 200 metres apart. Directly underneath the aerial down lead is placed the feeder house containing the aerial tuning and coupling units.

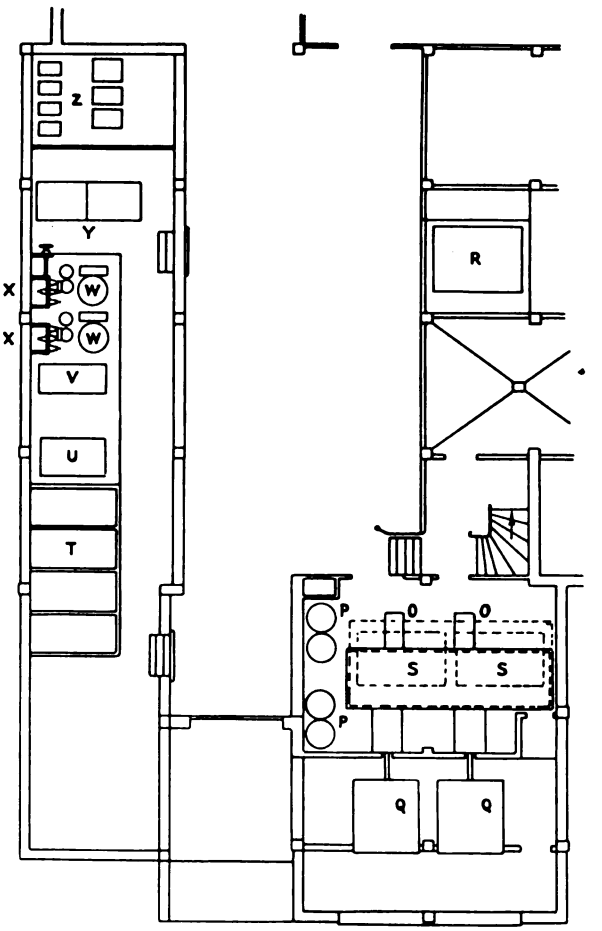

FIG. 7.

In order to secure minimum losses, the towers are insulated from ground and the high frequency and modulated energy is brought from the transmitting station at a distance from the aerial system by means of an aperiodic feeder circuit of low loss and negligible radiation.

Owing to the large number of thunderstorms which occur in this mountainous district, special lightning protection is provided for at the base of the towers, and at the point where the aerial is led into the feeder house.

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Earth System.

This consists of a number of metal plates buried vertically in the ground in the form of two concentric circles of earth plates. These rings of plates are connected by insulated wires to the main earth terminal in the feeder house.

The earth system is further extended in a radial fashion under the aerial by a large number of copper wires buried in the ground and extending practically over the whole of the site.

The principal electrical characteristics of the aerial system are :—

Capacity, ·0007 m.f.
Natural period, 720 metres.
Effective resistance for the working wavelength of 459 metres, 50·4 ohms.

Electric Power Supplies, Motor Generator and Switchgear.

The electric power required for operating the broadcast installation is obtained from the 3 phase 50 cycle supply at approximately 11,500 volts and transformed down to a low voltage supply at 380 volts as required for the motor generators and auxiliary circuits. The power supply is 11,500 volts for the main power mercury arc rectifiers.

The high voltage direct current required for feeding the power amplifiers is provided by a Brown Boveri mercury arc rectifier, already described.

The mercury arc rectifier chambers are duplicated and means are provided for switching either one into circuit.

Duplicated motor generators are installed for the purpose of providing the low voltage direct current required for heating the filaments of the power valves, grid negative supplies and for the H.T.-D.C. supply required for the modulated amplifier stage.

An all-metal built-in main power switchboard is provided for the purpose of controlling the various machines and auxiliary circuits, excepting the accumulator battery circuits, which are separately controlled from another switchboard installed in the transmitter room.

The total electric power required for operating the transmitter at full power (60 kw. 75 per cent. modulation), is approximately 260 kw.

Electrical characteristics of plant :—

Arc Rectifier, D.C. Output	270 kw. 12,000 volts.
Filament Lighting Motor Generators ..	1,200 amps. 10/25 volts. Exciter 110 volts.
Grid Negative Motor Generators	·5 amps. 1,500/2,500 volts. ·5 amps. 350/500 volts. ·4 amps. 200/300 volts.
Modulated Amplifier H.T. Generators ..	·5 amps. 2,500/3,000 volts. Exciter 110 volts.
Water-cooling Radiators, each	Heat dissipating capacity 92,000 g.c. per hour.

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Valve Water Cooling Equipment.

The system employed for cooling the water after it has been passed through the valve water jackets is shown in Fig. 6.

The essential features are :—

(A) Closed circulating system. By this method the same water is continuously circulated through the valve jackets. The heated

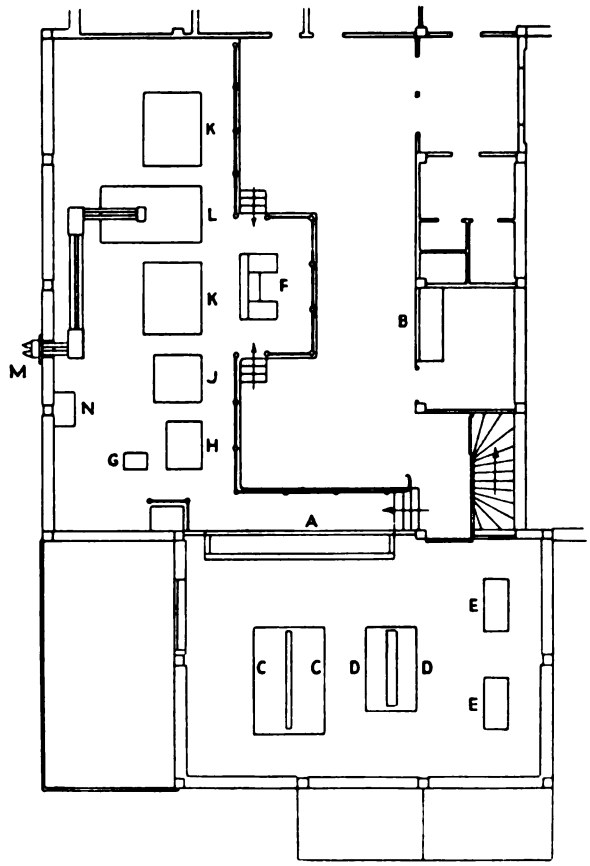

FIG. 8.

water as it comes from the valves is cooled by passing it through a tubular radiator through which is forced a blast of air by means of a motor driven fan. By the use of a closed circulating system it is rendered possible to use pure water of high electrical resistance for cooling the valves.

(B) Air pressure water feed tanks. This method provides a supply of cooling water at the correct pressure for cooling the valves,

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and the need for mounting overhead tanks is obviated. Further, the whole of the water cooling plant can be placed in the basement of the building. This simplifies the problem of preventing freezing during the winter months. Also the water pressure to the valve can be conveniently regulated to meet requirements. A complete set of automatic and semi-automatic controls is provided in order to secure a reliable and continuous supply of cooling water to the valve jackets at the required temperature, pressure, and volume. The water cooling system is in duplicate and the capacity is such that only one half is in service under normal conditions.

General Arrangement of Installation.

In Fig. 7 is shown the position of the plant in the ground floor of the transmitting building.

The air cooled radiators (Q) are contained within an enclosure. The fresh air is taken in at the right, blown through the radiators and exhausted into the air in front of the coolers. The two pairs of pressure water tanks each of 900 litres capacity, are shown on the left.

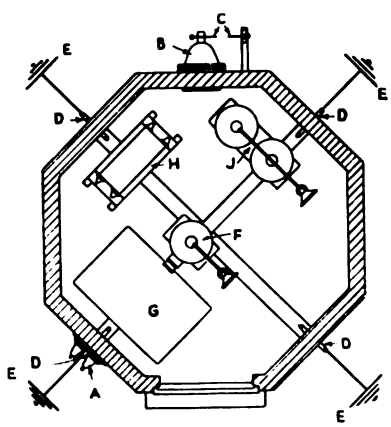

FIG. 9.

The duplicated pumps (O) are mounted over the covers of the inter-connected twin sump tanks.

On the left there is the H.T. enclosure and the power supply cubicles (T). Rectifier power regulating transformer (U), Power transformer (V), and alongside are the duplicated mercury arc rectifier chambers (W), with their auxiliary apparatus, insulating coils, oil and mercury vacuum pumps and heating transformer.

At the far end of the enclosure is the H.T.-D.C. switch panels (Y), and behind these are the H.T. condensers and chokes comprising the smoothing circuit (N) for the rectified alternating current. On the left is shown the rain water storage tank (R).

In Fig. 8 is shown the layout of the plant and equipment on first floor.

The main power control switchboard (A) is built into the wall dividing the transmitting and machinery rooms. The battery charging switchboard (B) is also of all-metal construction and built in, and provides for the charging of the accumulator batteries required for supplying current H.T. and L.T. for the drive and speech input units. This latter unit is placed in the engineer's office. Items (C), (D) and (E) are the valve filament heating, grid negative and modulated amplifier H.T. motor generator sets.

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The desk type control unit (F) is placed in front of the main transmitter panels; valve drive unit (G) is next to the combined modulator and modulated amplifier unit (H).

(J) is the intermediate modulated amplifier. (K) and (K) are the main power amplifiers unit, (L) contains the main closed high frequency circuits within a screened enclosure from which a pair of feeder lines lead to the feeder terminal unit (M), placed in the wall of the building, (N) is the mercury arc rectifier remote control unit.

The feeder house is placed underneath the centre of the aerial system and within this building are placed the following units, as shown in Fig 9:—

(A) Feeder Lead-in Insulators.
(B) Aerial Lead-in Insulator.
(C) Aerial Lightning Arrestor.
(D) Earth Lead-in.
(E) Earth Connections.
(F) Feeder Condenser.
(G) H.T. Air Condensers.
(H) Aerial Inductance.
(J) Aerial Tuning Series Condenser.

H. A. EWEN.

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ECHO SIGNALS IN TRANSATLANTIC PICTURE TELEGRAPHY.*

By H. M. DOWSETT.

PART I.

The Paper describes the various types of multiple signals and their causes, the influence of the Heaviside layer, and then gives a history of investigations carried out by the Marconi Company into short wave propagation phenomena covering the period from 1925 to 1931.

The facsimile echo signals discussed were all received at the Somerton Station of Imperial & International Communications, Ltd. They were transmitted on the dates given from the New York station of R.C.A. Communications, Inc., the Montreal station of the Canadian Marconi Company, and the Capetown station of Overseas Communications of South Africa, Ltd. The research was in charge of Mr. T. L. Eckersley, and Mr. K. W. Tremellen was responsible for the signal strength measurements quoted.

General.

THE subject of echo signals, which I have been invited to discuss in the present paper, concerns the now well-known phenomenon that a single dot signal transmitted by short wave radio to a distance, when received on a tape or photographic recorder running at a sufficiently high speed, may be found to have become split up during its passage through the atmosphere into a series of dots instead of one dot, thus producing the effect of a repetition of the signal or what is called " multiple " or " echo " signals.

The importance of the study of this subject is becoming widely recognised, as it bristles with problems that are vital to the art of radio communication, and the efforts of the physicist, the mathematician, the engineer, and the inventor are therefore being applied in an increasing degree to their solution.

The existence of echo may impose a serious limitation on the speed at which we can transmit telegraph signals without serious distortion of wave form and readability ; it may render telephony unintelligible, and restrict the speed of facsimile to that at which the echo images overlap the main image. How best to eliminate echo has therefore become one of the major problems of radio.

The presence of echo is not always, however, a bad feature. In slow speed transmission the energy of the echo signal is added to that of the main signal so that the field strength at the receiver is increased ; and as echo exists as a result of the electrical characteristics of the medium through which the signals are propagated, a systematic study of echo periods has enabled the mathematical physicist to fill in many gaps in our knowledge of the state of the upper atmosphere where the wave propagation takes place.

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* A Paper read on December 9th, 1931, before the Television Society at University College, London.

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Antipodal Effects.

It had been anticipated by Marconi and others that signal broadcast from any given station would travel in all direction round the world and converge at the Antipodes, so that a greater field strength would be found in the antipodal region than just outside it.

This was actually proved by field strength measurements made on board the sloop *Aldebaran* during her voyage to the Pacific in 1920 to study radio propagation phenomena for the French Government. As reported by M. Guierre, it was found for instance that signals from Lyons on 15,100 m. increased at the Antipodes so that they were stronger than those from other European stations, and when the ship reached the Antipodes of Nantes, wavelength 11,000 m., a similar strengthening of the Nantes signals was noticed.

Long Wave Interference Effects.

The first recorded case of interference effects being observed between signals, which were proved to be arriving by different paths from the same transmitting station was in March, 1922, when N. M. Rust, an engineer of the Marconi Co., who had been sent to South America with apparatus for the measurement of signal strength, and the direction of signals, to obtain information required for the design of the long wave stations projected for the Imperial Chain, made the following report from Cabo Frio, Brazil :—

> " With this adjustment we determined that NPO (Cavite, Philippine Islands) came in entirely from the East. . . . Later we found NPO coming in weakly from the West and decreased in the East. At a certain point the two intensities were equal. . . . With a bi-directional receiver very peculiar effects were noted. The two waves coming around the earth in opposite directions over different paths, were constantly changing in their phase relations, and consequently interfered, sometimes adding, sometimes cancelling. . . . Under these conditions NPO was unreadable on a bi-directional receiver because of the interference, but was readable with a uni-directional receiver with maximum either East or West."

The wavelength of NPO was 14,300 m.

Almost at the same time, a similar effect was recorded by another Marconi engineer, K. W. Tremellen, engaged on the same work on the S.S. *Dorset*. In a report from Auckland, New Zealand, dated March 29th, 1922, he wrote :—

> " About the 18th March, 1922, a peculiar effect was noticed on Rocky Point. His signals were blurred . . . at first we thought his key was sticking or he was being interfered with by another C.W. station on the same wave . . . and we got an idea that signals were coming both ways round and interfering with themselves . . . this effect has been noticed right up to Auckland and has been chiefly noticed on WQK (Rocky Point), WGG (Tuckerton), and to rather less extent on WII (New Brunswick) and WSO (Marion), with a suspicion on OUI (Hanover) and POZ (Berlin) . . . it seemed rather incredible that signals should come round the wrong way from NY (New York) even though it is the dark way."

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These observations of Tremellen's were actually checked by him with a direction finder and confirmed. The wavelengths concerned were of the order of 16,000 metres.

It may be remarked that interference effects between long waves have a greater likelihood of being observed when the receiving station is several thousand miles away from the transmitting station.

The proof that a long wave signal is able under certain conditions to completely encircle the earth is not easy to obtain, but that this effect does occur was verified by N. M. Rust in the winter of 1923, when using a Bellini-Tosi aerial giving a heart-shaped diagram at Chelmsford, so arranged that its minimum was in the direction of Carnarvon. This aerial normally received clearly defined weak signals from Carnarvon, wavelength 14,000 metres, obviously arriving by the direct route. Occasionally, however, at certain periods in the morning, when conditions were favourable for round the earth reception, a beat effect was noticeable similar to that observed in Brazil, which was explained by the interference between the direct ray and the round the earth ray travelling in the opposite direction.

Short Wave Round-the-Earth Echo Signals.

Echo signals were reported by A. W. Langridge in July, 1925, when listening at Brentwood to signals from Poldhu on 25 metres. They occurred at a time after sunset which we now know to be a suitable one for the propagation of round the earth echoes on this wavelength.

During the month of June, 1926, echoes of the order of one-seventh second corresponding to the complete circuit of the earth were regularly observed at Broomfield by K. W. Tremellen, following the signals from the short wave transmitter AGB (Berlin) on 26 metres. These echoes occurred about the sunset period, the echo signals following the shadow band at this time.

Short Wave Echoes due to Scattering.

From the commencement of short wave working, a type of echo signal which produced a blurring effect had been noted, having an interval of one-twentieth or one-thirtieth second after the receipt of the main signal. These echoes were investigated at Chelmsford on the cardioid direction finder in 1926.* They were specially marked at times during the dark hours on signals from AGB (Berlin) 26 metres, and whereas the direct signals from Berlin were received from the East, these echo signals were shown by the cardioid receiver to be coming at this time from a westerly direction. The distance could be calculated, and it was found that they came from a reflecting or scattering region within the skip distance.

A region of this type is never very clearly defined.

These echoes are troublesome because the main signal in the skip is received by the direct ray, and is frequently weak. Echoes of this nature were first photographically recorded by Quack, and by Taylor and Young.

* T. L. Eckersley, "Short Wave Wireless Telegraphy." Journal I.E.E. Vol. 65, 1927.

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Short Wave Echoes due to Multiple Reflections.

The attempts made by the Marconi Co. to introduce high speed facsimile between Somerton and New York in July, 1928, brought to light the existence of a type of very quick echo having a lag on the main signal which may be anything from 0·0007 to 0·006 second.†

These so-called echoes have a strength comparable with that of the main signal, and cannot be separated from it. In fact it seems clear that they really form part of it, being due to rays which reach the reflecting and refracting layer at a slightly different angle to those which constitute the main signal.

Very Long Period Echoes.

There are in addition echoes which are very rarely observed, having a period from one to two seconds up to several minutes, the cause of which is still unknown.

They are of scientific interest only at the moment and need not be discussed here, as they affect commercial working no more than does an occasional atmospheric.

Of these various types of echo, the echoes due to scattering and the echoes due to multiple reflections are the most serious in their distortion effects on the shape of high speed signals, whether the transmission considered is telegraphy, facsimile or television.

The Propagation of Short Waves through the Atmosphere.

If we are to understand the conditions that produce these types of echo, we must study the manner in which the electro-magnetic waves are propagated through the medium and the general characteristics of the medium.

We know for instance that if an aerial is radiating about 1 kw. on a wavelength of about 20 metres during daylight, the field strength falls off quickly with distance, so that at about 100 k.m. away telegraph signals may be too weak to read, but if we continue to increase the distance from the transmitting aerial we find that the signals come on again at about 800 km., and increase in strength for another 100 km. or so before commencing to gradually fall off once more.

By using a frame aerial receiver, it can be shown that the signals up to 40 or 50 km. are carried by rays which travel almost parallel to the earth, and therefore they remain in the lower atmosphere, whereas those which are received at 800 km. and over are conveyed by rays which reach the earth from the upper atmosphere at an angle of 20 to 30 degrees with the ground.

In this case, propagation is said to take place by "direct ray" for the first 40 or 50 km., and by "indirect ray" beyond 800 km., and the range between 40 or 50 km. and 800 km., where signals are either weak and unreliable or vanish altogether is called the "skip distance."

† T. L. Eckersley, "Multiple Signals in Short Wave Transmission." Proceedings Inst. Radio Engineers. Vol. 18, No. 1, January, 1930.

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The Heaviside Layer.

As the indirect ray reaches the earth at an angle, it must have passed through a region in the atmosphere which is capable of bending it down, or refracting it, and this region is called the Heaviside layer.

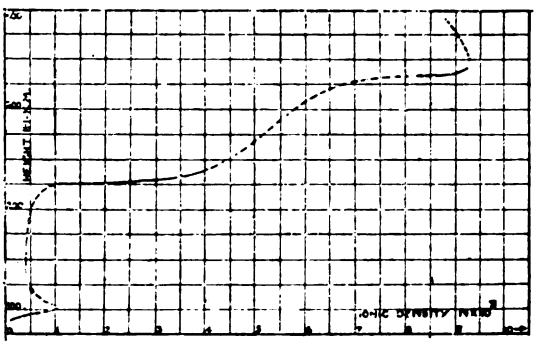

FIG. 1. *Ionic density in the Heaviside Layer.*

The present day explanation of why these short wave rays are bent down again to the earth is as follows :—

We know that the upper atmosphere is ionised, and twenty years ago it was shown by Eccles that if the ionic density is great enough, and the air pressure is so low that the free path of the electrons between the gaseous ions is sufficient for them to respond to the ray impulses without such motion involving collisions with these ions, or with the neutral molecules, then the motion of the electrons should impart a phase shift to the wavefront of any electro-magnetic pulse in the medium, causing the wavefront to bend forward and the rays in consequence to bend downward.

Experimental research of late years has done much to confirm this theory, but it will be realised that in order to calculate the strength of signals at a distance this theory must be strongly reinforced with data, and there are several factors which we require to know.

We have to determine

(A) The height of the Heaviside layer.
(B) The ionic density in it.
(C) The density of the air in this region.
(D) The mean free path of the ions at this height.

The range obtainable on any of the short wavelengths is also found to depend on the height of the sun relative to the great circle through the transmitting station in the direction considered.

The sun in fact is responsible for the ionisation in the daytime of that part of the upper atmosphere which is immediately below the main Heaviside layer, and this introduces another factor we require to know :—

(E) The re-combination factor which takes into account the change in the ionic density from daylight to night conditions.

The experimental and mathematical research work of many investigators in this country, in the United States and in Germany, particularly of Eckersley, Appleton, Breit, Tuve, Dahl, Kenrick and Jen, has enabled us to form a physical picture of the Heaviside layer and its general characteristics, which is as follows :—

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Ionic Density, Refraction and Absorption in the Layer.

At a level of about 80 km. above the earth, the ionic density in winter is becoming appreciable, and the mean free path between atoms is increasing, but it is not until a region of about 100 km. above the earth is reached, where the ionic density N has a value of 10^5 per c. cm., and the mean free time between collisions lies between the limits $0{\cdot}5+10^{-6}$ and $0{\cdot}5+10^{-7}$§ that conditions exist which can cause the incident indirect rays of certain frequencies to be refracted down to earth again.

The lower limit of free time would allow ray frequencies corresponding to wavelengths of 150 metres and less to be refracted, while the upper limit would reduce the value of maximum wavelength to be refracted to 15 metres.

Above these limits of wavelength, and certainly above 150 metres, refraction must be accompanied by absorption as ionic collisions take place within the periodic time of one oscillation. For all wavelengths above 1,000 metres, no ray passes through the 100 km. layer, they are all absorbed in it. While there is some bending at all these wavelengths, the lower angle rays travel greater distances than the rays of high angle, as there is less absorption in the lower atmosphere than in the layer.

Wavelengths from 1,000 metres down to 100 metres are also all confined below the 100 k.m. layer, but they experience in the lower atmosphere an increasing absorption and a decreasing absorption in the 100 km. layer as the wavelength is made shorter. Reflections from the layer therefore increase as the wavelength falls.

From 100 metres down to about 70 metres it would appear that in general the 100 km. layer reflects all rays up to vertical incidence, but occasionally the ionic density is not sufficient to completely confine all the higher angle rays of the shorter wavelengths, and these escape through to a still higher layer at an elevation of about 212 km., where the ionic density is approximately $2{\cdot}4\times10^5$ per c. cm., or about $2\frac{1}{2}$ times the density of the 100 km. layer. This second layer refracts down to earth all the high angle rays of the 100 to 70 metre wavelengths that escape through the lower layer. It is on these wavelengths that multiple signals are very pronounced. From 70 metres down to about 9 metres there is every indication, confirmed in particular by T. L. Eckersley's analysis of echo signals obtained on a Transatlantic facsimile channel, that the lower angle rays are refracted by the 100 km. layer, rays of a greater angle are refracted down at the 226 km. layer, and there is also strong evidence of refraction at a height of about 340 km., where the ionic density is about 9×10^5 per c. cm., or nearly 10 times the maximum value of N at the 100 km. level, and is sufficient to bend down all the high angle rays of the longer wavelengths of this group which escape through to it, and most of the high angle rays of the shorter wavelengths of the group.

Thus from some facsimile echoes obtained on 22 metres between New York and Somerton, it was calculated by Eckersley that the maximum ray angle was 9° for the 100 km. layer, higher angles were refracted from the 340 km. layer, and some rays up to vertical incidence escaped completely through the 340 km. layer.

§ T. L. Eckersley, "An Investigation of Short Waves." Journal I.E.E. Vol. 67, p. 992, 1929.

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While it appears to be established that there is a distinct fall in ionic density between the 100 km. and 212 km. levels, as indicated in Fig. 1, there is some likelihood that there is a gradual increase in ionic density from the 212 km. level to the 340 km. level, above which our probing methods have not succeeded in penetrating.

At 15 metres, the 340 km. layer does nearly all the refraction that occurs, and high angle radiation escapes through it to an increasing degree. At wavelengths less than 9 metres signals are conveyed by direct ray only, as all rays that reach the Heaviside layers pass through them.

Such in brief is the picture which is presented to us of the refracting region of the upper atmosphere during daylight, and in winter, to which we have to look for an explanation of the very quick echo which has been found to be so prevalent in Transatlantic facsimile.

In summer daylight the ionisation is greater, and the lower parts of the layers are therefore nearer to the earth. As the ionic density is greater, more high angle rays are bent down to the earth, so that multiple echoes should increase, and as the shorter wavelengths will not escape through the layers so easily, they will become more available for long distance communication.

It can be shown that if the gradient of the ionic density remains the same, then the signal strength at all points will be the same if $\lambda^2 N$ remains constant.

Thus let the normal density N fall in winter to half what it is at the same hour in summer, then the same strength signals will be given in winter by a wavelength 1.4 times the summer wavelength. The normal density, however, does not vary as much as this.

As soon as the sun has passed the zenith, the ions commence to re-combine. They are in no great hurry about it, as it appears that the ions at the 340 km. level are free for about four hours. At nightfall the density throughout the layer has become considerably less, but the minimum point is reached just about sunrise. The lower fringes of the layer are now higher than before, although they are still within 20 miles of the normal. There is less absorption at the 100 km. level and more at the 340 km. level. More high angle rays escape through than during the daytime, so that signals on a given wavelength should be weaker and there should be less echo, and a longer wavelength should give stronger signals than the original daylight wavelength.

(*To be continued.*)

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DIRECTION FINDERS

TYPES D.F.G.9A & D.F.G.9B

The Direction Finder Type D.F.G.9a has been designed principally for use with the small type of shielded frame aerial, and this combination has proved particularly suited to naval conditions where rapid manipulation, both as regards waverange change and directional observation, are of prime importance. In order to extend the usefulness of this instrument into the general purpose category, subsequent modification has resulted in the model styled D.F.G.9b, and these two instruments represent the Marconi Company's most recent development in this class of work.

The Type D.F.G.9a receiver is described in this article and will be followed by a description of the D.F.G.9b at an early date.

WITH regard to the design of Direction Finding apparatus for naval work, modern demands impose four important conditions in addition to the usual requirements of range and accuracy.

(1) The reception diagram must be capable of denoting the direction of a distant transmitter by a sharply defined " zero " signal.

(2) Simple tuning and rapid waverange change.

(3) All vital component parts of the apparatus must be easily accessible for inspection and maintenance.

(4) The mechanics of the complete assembly must be sound in every detail.

In the Direction Finder D.F.G.9a, the well-established advantages of the aperiodic Bellini-Tosi system have been retained, but the entire design is based on the above specified conditions.

The first important feature is the inclusion of a supplementary circuit (coupled to the amplifier) for the purpose of sharpening scale definition at the point of " zero " signal.

The tuning condensers and also the H.F. transformers of the main amplifier are ganged and a separate heterodyne is employed for the reception of C.W.

The complete amplifier may be withdrawn or removed entirely from the instrument assembly without disconnecting a single wire, and the action of withdrawing the amplifier automatically breaks both H.T. and L.T. supplies.

Carefully machined castings ensure reliable mechanisms and sturdy construction.

This instrument is intended to be combined with Frame Aerial Type 354N/32, which is illustrated in Fig. 1.

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The complete instrument, which is shown in Fig. 2, comprises two main units :—

(1) The radio-goniometer.

(2) The amplifier and associated circuits, which include zero sharpening device and a local oscillator.

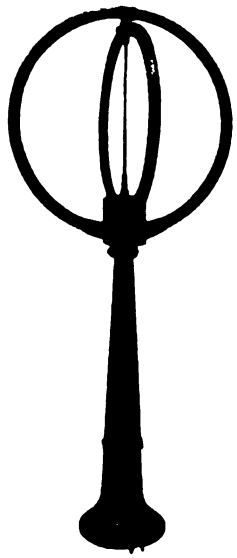

FIG. 1.

The goniometer is of recent pattern with large open scale and double ended pointer. Field coils have spaced windings of low inductance, and the search coil, which is loosely coupled, is tuned over the entire waverange of 300-4,000 metres. For the purpose of quadrantal correction, each field coil may be shunted by a variable inductive choke, and these components are contained in the goniometer unit. The search coil is connected by flexible screened cable to its tuning components in the top left hand compartment of the amplifier unit. This circuit includes a screen grid valve whose output is transformer coupled to the main amplifier. The amplifier, which occupies the whole of the lower section of the instrument, comprises two H.F. screen grid stages (transformer coupled), leaky grid detector, and two note magnifiers, the first of which is coupled by resistance capacity, and the second by an iron core transformer. An output transformer provides for low resistance telephones and isolates the headgear from high tension voltages.

The system of ganging for the main amplifier permits of easy readjustment or checking when desired. For the purpose of adjustment, the condenser stators may be advanced or retarded with respect to the moving vanes by slackening the appropriate pinch bolts and engaging push rods provided for the purpose. These rods are inserted through bushed holes in the front panel of the amplifier, and register with tapped collars on extensions of stator spindles. When a final setting for all circuits is obtained, the condenser stators are locked and the push rods removed. These rods, together with a locking spanner, are stored in a small rack inside the amplifier. The ganged condensers are bevel driven and are controlled from the front panel by a vernier dial suitably calibrated in metres. A simple adjustment allows all trace of backlash to be removed in the event of wear (Fig. 3).

Waverange change is effected on the commutator principle, that is, the required number of H.F. transformers per stage are contained on the same cylindrical former which is capable of rotation within a frame carrying brush contacts to which the

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circuit components are connected. All three transformers are mechanically coupled so that they operate together and are controlled by a 4-position lever from the front of the main amplifier panel. In this way multi-waverange reception is

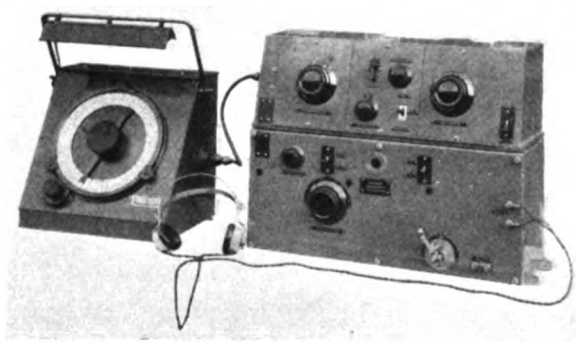

FIG. 2.

accomplished without increasing the stage and interstage wiring over and above that required for a single waverange. Provision is made for short circuiting the grid coils adjacent to those in use during manipulation. This is to prevent absorption resulting from undesirable resonances. Figs. 3 and 4 show the transformer

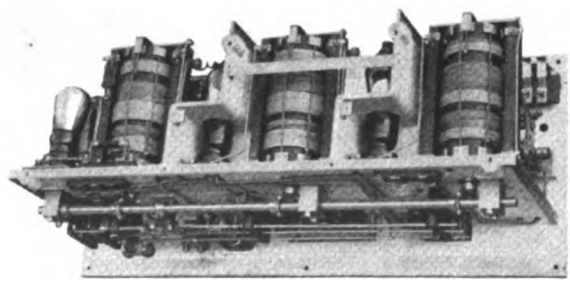

FIG. 3.

mechanism, and also emphasise the small amount of amplifier wiring. Each transformer may be removed from the amplifier, complete with its frame, contacts and bevel by removing six screws, which also release the compartment wiring.

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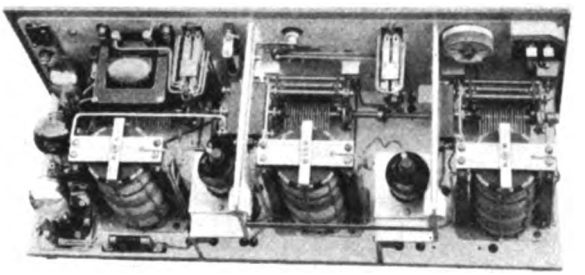

The amplifier provides for four waveranges, as follows :—

Range	1	300-600 metres.
,,	2	600-1,400 ,,
,,	3	400-2,800 ,,
,,	4	2,800-4,000 ,,

FIG. 4.

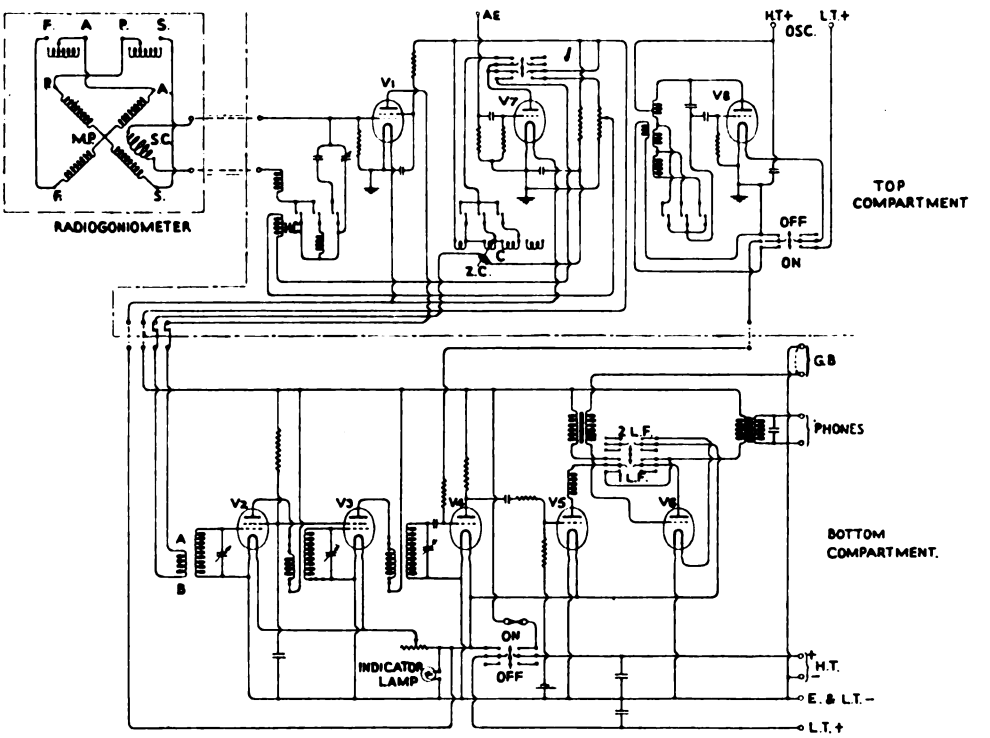

FIG. 5.

With regard to the three compartments in the upper portion of the set, that on the left contains the search coil tuning components; in the centre are the zero-sharpening and "sense" circuits, and in the right is the local oscillator. These three sections are controlled by a ganged switch which covers the waverange in three steps, as follows :—

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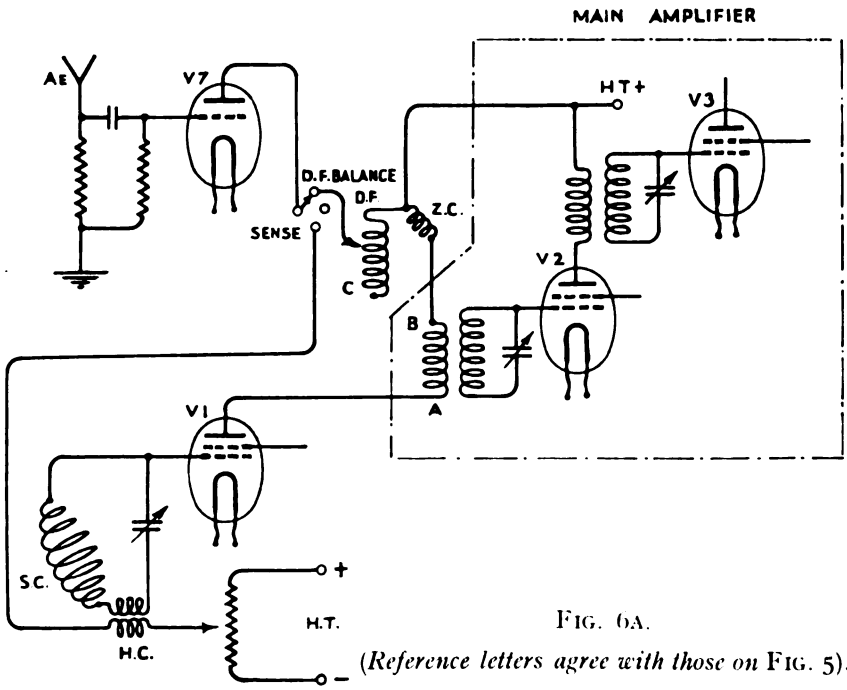

FIG. 6A.

(*Reference letters agree with those on* FIG. 5).

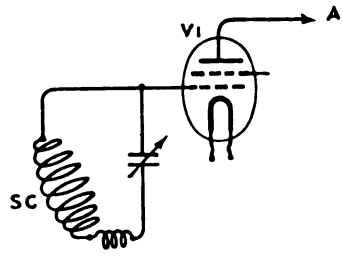

FIG. 6B.

D.F. position.

No coupling from vertical aerial.

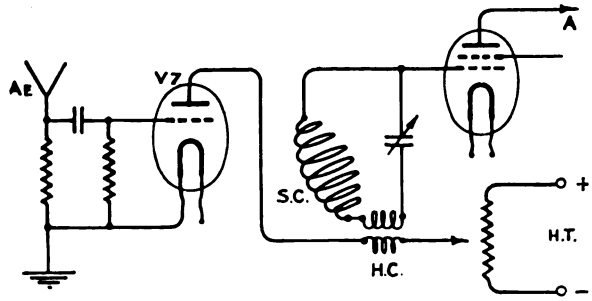

FIG. 6C.

Sense position.

Vertical aerial coupled to search coil to convert polar diagram from figure of eight to cardioid.

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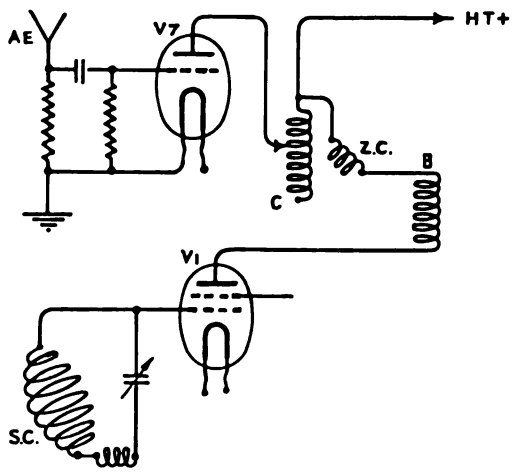
Range 1 . .	. .	. . 300- 900 metres.
,, 2 . .	. .	. . 900-2,800 ,,
,, 3 . .	. .	. . 2,800-4,000 ,,



D.F. balance position.

Vertical aerial coupled to amplifier to balance for sharp zeros.

FIG. 6D.

A selector switch for spark or C.W. is positioned at the lower right hand side of the oscillator compartment. Search coil and oscillator circuits are calibrated in metres.

L.T. and H.T. supplies for the amplifier are normally 2 volts and 120 volts respectively, but 4 or 6 volt valves may be used if desired. Screen grids are fed through a drop resistance from the H.T. busbar within the instrument.

In the event of a power valve being desired in the last stage, provision is made for connecting additional grid bias external to the set. The electrical arrangement of the complete instrument is shown in Fig. 5.

A small vertical aerial is used for the dual purpose of "zero-sharpening" and sense. The pickup from this aerial is amplified by a separate high frequency valve, the output from which is controlled by the D.F. "sense" switch in such a manner that the anode circuit may be coupled either to the main amplifier for zero-sharpening or to the search coil for "sense." In the "sense" position the anode supply to this extra valve is fed by a potentiometer, and on this control the reception diagram may be varied from "all round" to "cardioid."

The zero-sharpening and "sense" circuits are shown schematically by Fig. 6.

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MARCONI NEWS AND NOTES

MORE NEW MARCONI BROADCASTING STATIONS

BROADCASTING has become a regular feature in the lives of civilised peoples throughout the world, and growing licence figures from every country indicate that its popularity is still rapidly increasing after more than a decade of remarkable progress. Marconi broadcasting installations have played a considerable part in the advance of this new art and science, and recent orders include a new Marconi station for the completion of the "regional" broadcasting scheme in Switzerland, and another to be erected in Buenos Aires.

The new station for Switzerland is a Marconi Type P.A.19a installation and it is to be erected on Monte Ceneri, near Tessin, in Italian Switzerland, where it is expected to be in operation by the end of this year. It will have an energy of 15 kilowatts unmodulated power in the aerial.

The new Marconi station at Buenos Aires will operate on a power of 20 kilowatts and will serve a large area around the Argentine capital. Regular transmissions, under the control of Radio Excelsior of Buenos Aires, are expected to commence early next year.

Before either of these stations are heard, however, the new Marconi high power broadcasting station in the Irish Free State will be opened. A special effort is being made to prepare the station in time for the Eucharistic Congress in June, as it is desired that the powerful new voice of the Free State shall be inaugurated by a special series of broadcasts of this event. The station will have an unmodulated aerial energy of 60 kilowatts, and arrangements have been made whereby its power can be doubled at a later date.

Novel Marconi Apparatus.

A NOVEL type of apparatus (illustrated on page 29) has been constructed by the Marconi Company for use in Northern Rhodesia, to link up the many isolated administrative posts in the territory with each other and with Government headquarters by means of short-wave wireless communication.

The wireless equipment consists of a Marconi Type A.D.19 transmitter, this being an aircraft transmitter of 150 watts power, embodying an independent drive and having a wave range of 40-60 metres, and a Marconi Type R.G.28 receiver with a wave range of 10-200 metres. Power is derived entirely from a tandem pedal-

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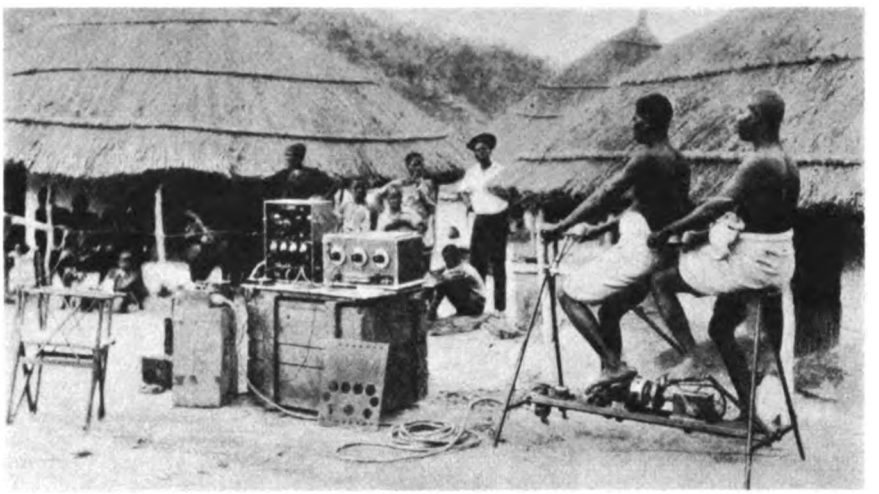
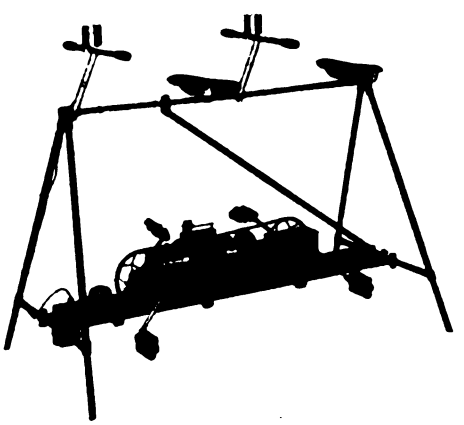


Marconi equipment with pedal-operated generator in use in Northern Rhodesia.

driven generator which supplies both high and low tension circuits, the high tension supply being 1,000 volts at 130 milliamps., and the low tension supply, 9-10 volts, at 6 amperes. To indicate the correct pedalling speed, voltmeters, marked at only one point, are fitted on each handle bar, so that when native workers are employed in pedalling they can be instructed to maintain a speed that will keep the voltmeter needle on that mark. The pedals are connected by a chain, and drive the generator through suitable gearing, a flywheel being fitted to ensure a sufficiently steady output. This simple but effective power plant can be driven continuously without undue exertion, and the native pedallers are said to enjoy thoroughly this new form of physical exercise.



The pedal-operated generator.

During tests of the equipment, satisfactory communication was maintained over distances up to 500 miles, despite difficult atmospheric conditions.

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Marchese Marconi (with arm uplifted) explaining his new ultra-short-wave radio telephone apparatus to His Holiness the Pope (central figure in white) during recent tests of the apparatus in the Vatican grounds. On the conclusion of these tests Marchese Marconi was warmly congratulated by the Pope, who authorised the establishment of a wireless telephone service between the Vatican and his summer villa in the Alban Hills, for which the new ultra-short-wave system will be utilised.

Air-Taxi's Wireless Telephone.

AN air-taxi fitted with Marconi telephone equipment which enables the pilot to keep in touch with the ground wherever he may be flying over Great Britain, or practically throughout Europe, is the latest addition to London's transport facilities.

This is the Puss Moth machine flown by Captain Laurence Hope, of Air Taxis, Limited, which is being equipped with Marconi light aeroplane apparatus, Type A.D.22. Incorporating a special telephone transmitter as well as a receiver the apparatus enables the pilot not only to receive weather reports and other communications regularly broadcast from ground stations, but also at any time to speak to the aerodromes himself and ask for any information he may require for his guidance or assistance in the air.

Should he, for instance, encounter during flight a bank of fog or thick cloud he can call up the nearest suitable ground station, confirm his position by wireless

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direction finder, learn whether the conditions of bad visibility are local or general and judge with confidence whether it is possible to continue to his destination. Such services are regularly performed for the pilots of passenger-carrying aircraft on the regular air routes by such wireless stations as those at Croydon, Lympne, and Pulham aerodromes, and they are equally available to the owners of private machines fitted with wireless transmitters and receivers.

Captain Hope uses his Puss Moth air-taxi very largely for newspaper work, where speed is of the first importance, and he realises that on many occasions such information would be very valuable to him, enabling him to decide, while still in the air, the quickest and safest means of delivering his photographs or other Press matter. At the same time, he can inform his waiting colleagues of his movements so that unexpected delays are reduced to the minimum.

Captain L. Hope operating the Marconi telephone in his air-taxi. Inset: The equipment installed at the rear of the passenger compartment.

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Marconi Beam System.

CONGRATULATORY telegrams were exchanged between Mr. E. T. Fisk, Managing Director, Amalgamated Wireless (Australasia) Ltd., and the Marchese Marconi, on Friday, April 8th, marking the fifth anniversary of the opening of the Beam wireless service between England and Australia.

Mr. Fisk telegraphed :—

> "To-day is the fifth anniversary of opening Beam wireless service between England and Australia which has operated faultlessly from its inception. Please accept my personal congratulations upon this demonstration of the wonderful success and efficiency of your Beam wireless system. Greetings and kind regards."

Marchese Marconi's reply was as follows :—

> "Highly appreciate your remembrance and greetings on occasion fifth anniversary inauguration Beam wireless service between England and Australia which has so successfully confirmed my expectations. Wish you and your collaborators continued success."

Wireless for International Flight.

MARCONI wireless equipment has been chosen by Prince Bibescu of Roumania, President of the International Federation of Aviation, for a flight over Central Africa which he is to undertake in March under the auspices of the Federation. The flight is intended to be an international venture, with a Roumanian pilot, German aeroplane, French motors, and British wireless.

The selection of Marconi wireless equipment is a tribute to this Company's supremacy in this highly specialised phase of communications, for on many sections of his long flight Prince Bibescu will be traversing wild country and will be entirely dependent upon his wireless equipment for keeping in touch with his bases, obtaining weather and landing reports, and securing aid in case of emergency. During a considerable portion of the flight he will be able to communicate with the chain of wireless stations from Cairo to Capetown, most of which were erected last year by the Marconi Company for the Imperial Airways trans-African route.

Prince Bibescu's wireless apparatus will be the Marconi Type A.D.18a telegraph-telephone set, with emergency equipment which will enable him to transmit and receive messages on the ground in the event of a forced landing. In this special equipment a light collapsible mast enables a temporary aerial to be rigged in place of the trailing aerial used in flight, while the power generator, which is normally mounted in the slip stream and wind-driven, is operated by a small petrol engine.

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THE MARCONI REVIEW

May-June, 1932

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ENGINEERING

THE MARCONI REVIEW

No. 36. May-June, 1932

Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P., M.Inst.R.E.

ECHO SIGNALS IN TRANSATLANTIC PICTURE TELEGRAPHY.*

By H. M. DOWSETT.

PART II.

The Paper describes the various types of multiple signals and their causes, the influence of the Heaviside layer, and then gives a history of investigations carried out by the Marconi Company into short wave propagation phenomena covering the period from 1925 to 1931.

The first part of the Paper was published in THE MARCONI REVIEW, *No. 34, and dealt with the production of echoes during the propagation of short waves through the atmosphere. The concluding part of the Paper deals with the recent investigation of such echoes by the use of facsimile methods of reception.*

Recent Investigation of Short Wave Propagation Phenomena.

The main conditions affecting the propagation of short waves, which, as the result of extensive research work on the character and behaviour of the upper atmosphere have been found to exist, have been stated, and with this survey completed, it is proposed now to describe briefly the general sequence of investigations carried out of late years by the Marconi Co., on the propagation of short waves, the results of which have contributed so materially to the present accepted theory.

When short wave working was first applied to the commercial traffic services it was immediately recognised that if we could obtain reasonably approximate values for the height, ionic density, and attenuation constant of the refracting layer or layers, and a measurement was made of field strength received from a station at a known distance radiating a known power from its aerial on a known wavelength, it should be possible to modify the theory of propagation accepted for long waves so that it could be applied to short waves; and then by the aid of this revised theory it should be possible to calculate the strength of signals at any distance on any wavelength on which signal strength measurements at a fixed distance had been taken, and to interpolate values for intermediate wavelengths.

* A Paper read on December 9th, 1931, before the Television Society at University College, London. The blocks for these illustrations are kindly loaned by the Television Society.

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With this end in view, the systematic observation of the signal strengths of commercial short wave stations was begun at Chelmsford, which, together with the records of the preliminary tests of the beam stations covered the two-year period 1925-27, and as a result enabled the Marconi Co. to publish early in 1928 the two sets of curves shown in Fig. 2 and Fig. 3, for estimated signal strength at different distances up to 10,000 miles, covering a range of wavelengths from 6 metres to 100 metres ; Fig. 2 giving the results for all daylight transmission and Fig. 3 for all darkness transmission.

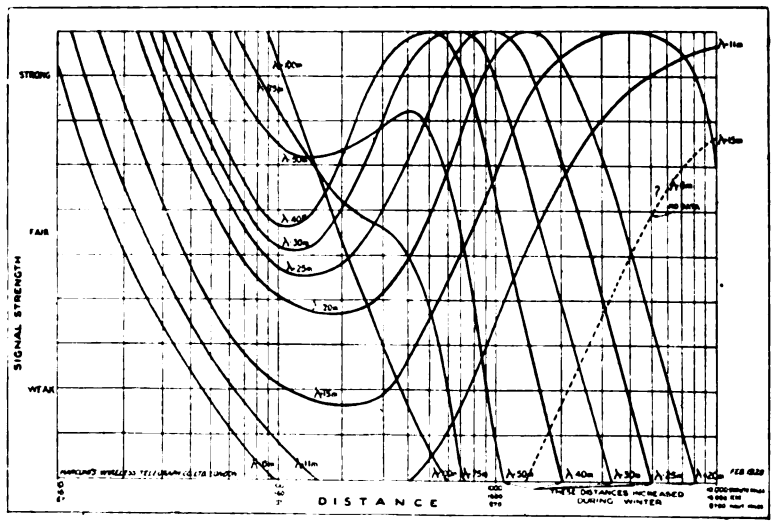

FIG. 2.—*Distance-Signal strength curves. Short Wavelength transmission during daylight.*

Their compilation was noteworthy, as it was the first attempt ever made to predict the strength of signals received at a great distance by the indirect ray, and over a wide range of wavelengths.

The curves were based on the signal strengths estimated in arbitrary R units by the operators employed on interception duty, where R1 indicated a signal that was just audible, and R9 a signal strong enough to be heard when the telephone was held away from the ear. They provided a first approximation to field strength values, no suitable apparatus for the quick and accurate measurement, as distinct from aural estimate, of field strength being at that time available.

The importance of this investigation having been recognised, arrangements were made for a period of continuous interception of short wave signals on wavelengths between 14 metres and 50 metres from stations all over the world, which varied in number increasing towards the end of the period up to a maximum of 120. This interception was carried out from October, 1927, to October, 1928. The signal intensities were again estimated in R strengths, and observations on the directions of the incoming signals were also made at the same time.

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The analysis of the results provided the material for two valuable papers,* published in 1929, dealing with the various problems of world-wide communications, including echoes, scattering, attenuation, fading, magnetic storm effects and skip effects, and also the construction of shadow charts, which enabled the transmission range on different wavelengths to be calculated, not only under all daylight conditions or all darkness conditions, but also with the sun at any position of elevation relative to the great circle direction considered.

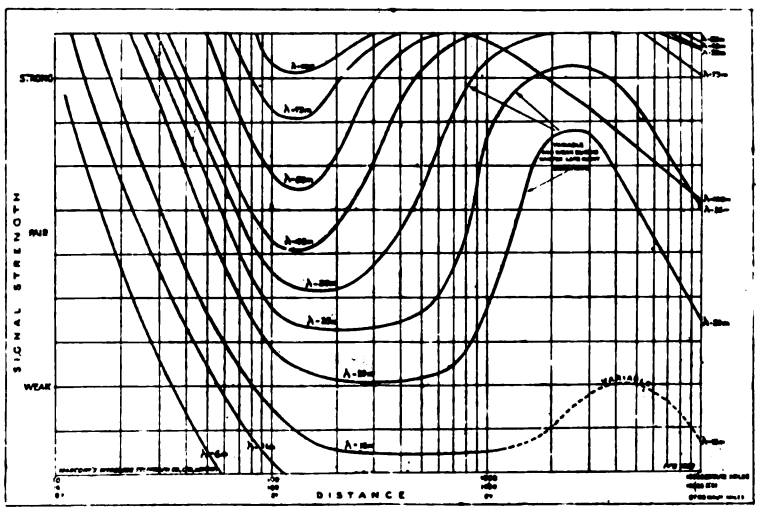

FIG. 3.

Distance-Signal strength curves. Short Wavelength transmission during darkness.

Then from August, 1928, to January, 1929, the facsimile echo tests between Somerton and New York on 22 metres, to which reference has already been made as having provided such useful information on very short echo times, height of refracting layer, ionic density in the layer and ionic re-combination factor, were carried out.

Several of the figures employed in this paper to illustrate the 22 metres results were first published in Eckersley's 1930 Multiple Signals Paper.

Marconi-Wright Facsimile Apparatus.

An illustration of the Marconi-Wright facsimile apparatus employed on the Transatlantic tests is shown in Fig. 4. This gives a view of the general assembly at the transmitter end, the apparatus on the right comprising an aperture disc for chopping up the light, with its driving motor. In the centre is the controlling switchboard, with the optical rotor and lens system in front. On the left is a panel carrying the amplifiers, the electrically maintained tuning fork control being mounted on a rack which is not shown.

* T. L. Eckersley, "An Investigation of Short Waves." Journal I.E.E. Vol. 67, p. 992, 1929.

T. L. Eckersley and K. W. Tremellen, "World-wide Communications with Short Wireless Waves." World Engineering Congress, Tokio, 1929.

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The general appearance of the facsimile receiver equipment is similar to the above.

A schematic view of the optical parts of the transmitter is shown in Fig. 5. A is the light source, C the chopper disc, and PQ the optical rotor which causes the light beam from the lens H to scan the surface of the picture to be transmitted, through a slot in a stationary brass cylinder. The picture is held down on the cylinder by means of a flexible band supported by a hinged carrier, and the carrier is made to move slowly forward carrying the picture over the optical slot by means of a lead screw. The scattered light from the picture surface is conveyed through the lens J and prism K to a photo-cell, and the current fluctuations which result pass through an amplifier system to the line and thence to the modulating system of the radio transmitter.

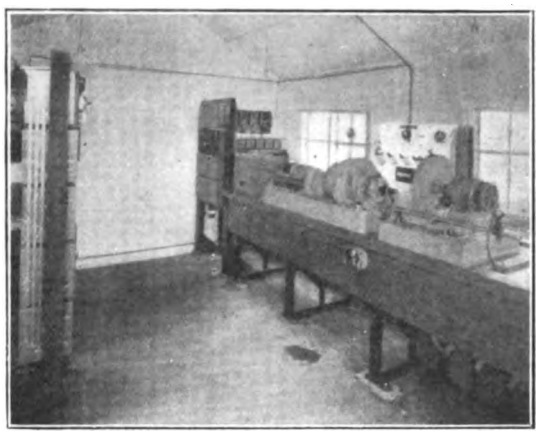

FIG. 4.
Marconi-Wright facsimile apparatus. Transmitter assembly.

The optical parts of the facsimile receiver used on these tests is shown in Fig. 6, where L is the light source, B a Nicol prism polariser, K a Kerr cell for modulating the light, E a Nicol prism analyser, through which the modulated light passes to the prism and scanning lens in the optical rotor. The sensitised paper is held down on the cylinder M by a flexible band and carrier, and is made to traverse the optical slot along which the scanning spot moves by the motion of the carrier on the lead screw. A photographic record is thereby obtained on the paper, which requires to be developed to complete the process.

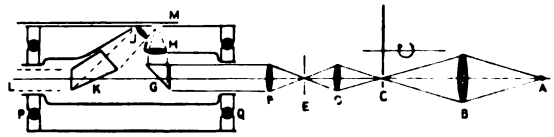

FIG. 5.
Marconi-Wright facsimile apparatus. Diagram of transmitter optical assembly.

The speed of the scanning spot, which is controlled by the fork, was adjusted for most of these tests to 30 ins. per minute, which was sufficient to distinctly separate signals of short duration such as of the order of 0·0002 sec., having time intervals between them of less than 0·001 sec.

Then if a single thin line is drawn on a sheet of paper transverse to the direction in which it is to be scanned on the facsimile drum, and conditions are suitable for echo, two, three or more thin lines will appear on the receiver print. It is usual to call the first line the main signal and the remaining lines echo signals. The speed of the scanning spot being known, the complete echo duration can be obtained

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from the distance between the first and last lines ; and the intervals between the separate echoes in a series, from the distances between the different lines.

Some Results of Facsimile Echo Tests on 22 Metres Somerton—New York Circuit.

The echo intervals are irregular, but occasionally a series is repeated many times within the period of a few minutes.

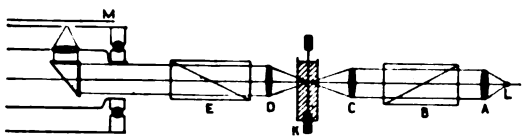

FIG. 6.

Marconi-Wright facsimile apparatus. Diagram of receiver optical assembly.

T. L. Eckersley takes a typical case of such echoes obtained on a facsimile print when transmitting a single thin line as described. As many as five signals were received for one signal sent at certain portions of the line, and several of these series of five signals when plotted on the same time scale almost coincided, as shown in Fig. 7. He was able to show that the first signal was due to a ray inclined less than 5° from the horizontal, the second to a ray having an angle of 16° 45′ ; the third to a ray inclined at 21° 34′ ; the fourth a ray inclined at 29° 32′ ; and the fifth a ray leaving the transmitter at an angle to the ground of 34° 36′.

He reasoned that these rays travelled as in Fig. 8, from A to a distant point by successive reflections, and he was able to enforce this conclusion by calculating the height of the reflecting layer to account for the echo times measured, with the result that three out of the five echoes gave figures for the height as follows :—

FIG. 7.

The periods of several multiple echoes superposed on the same time scale.

Echo No.	Height.
3	343 km.
4	338 km.
5	340 km.

and these results agreed with those obtained by Kenrick and Jen, when employing a pulse method at night on 67 metres, which indicated a layer of 344 km.

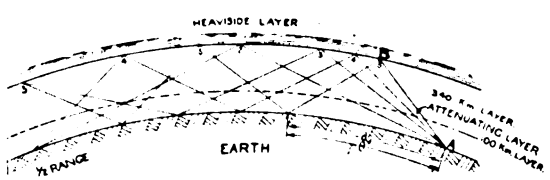

FIG. 8.

The production of multiple echoes by rays leaving the transmitter at different angles.

The effect of echo on facsimile prints made at different hours in the day is illustrated in Figs. 9, 10 and 11. Fig. 9 was taken at a speed of 30 ins. per minute, the length of the picture being 8 ins. It was taken near midnight when the signals were weakened by the falling off of some of the high

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angle echoes. Fig. 10 is a better picture, because it was taken in the early morning when echo is least, and also because the scanning speed had been reduced by half.

Fig. 11, taken in the afternoon when echo was prevalent, demonstrates that if the scanning speed is sufficiently reduced such as to a speed of 10 ins. per minute, so that the echoes overlap, the picture is clear and signals are strong, although a reduction in speed of the required order may render the traffic channel commercially unprofitable. By increasing the speed to 30 ins. per minute, the signals forming the different characters in the message were made to open out, with the result that intelligibility was lost.

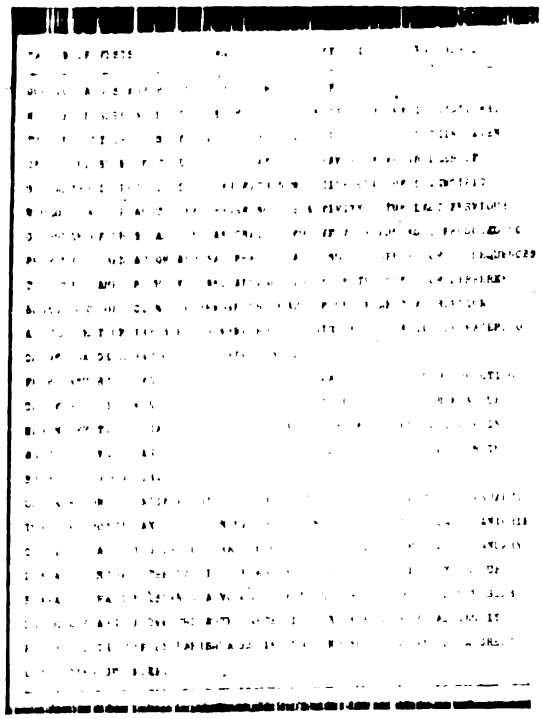

FIG. 9.

Effect of echo on a facsimile sent from New York to Somerton on 22 metres, speed 30 ins. per minute, at 2335 G.M.T., October 21st, 1928.

In general, the duration of the echo signal is directly proportional to the field strength of the main signals. Thus the curves of Fig. 12, taken at Somerton during the facsimile tests on 22 metres with New York in 1928, indicate that echo was negligible when signals were only just readable at 6.0 a.m., but had maximum duration at 6.0 p.m., when the field strength of the main signal was greatest.

Now it was hoped that every year the conditions of propagation would repeat themselves. Such, however, has not proved to be the case.

When the 1928-29 observations were used as a basis to estimate best wavelengths in 1930-31, the wavelengths found best in practice proved to be longer than those estimated, especially during the night.

Any doubts which existed regarding a possible change in conditions have recently been set at rest as the result of a further period of twelve months continuous observations on the transmissions of the world short wave stations, which concluded in September, 1931. Actual measurements of field strengths were taken in this series of tests, as distinct from the estimated field strengths judged by the intercepting operators, on which reliance had to be placed in the earlier tests.

Confirmation has been obtained that at the present time there is a progressive increase each year in the values of wavelengths which give best results.

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Further Long Distance Facsimile Tests.

Finally, in the middle of this last mentioned period, that is from March to June of this year, there took place the second group of facsimile echo tests on 15 metres and 30 metres between Somerton and Montreal, and also between Somerton and Cape Town, which have given results complementary to the field strength tests, showing that the ionic density for the same period in the year, day or night, has fallen considerably from the 1928-29 values. This explains the increase in the values of optimum wavelengths, and observations suggest that there is a connection between these changes and solar activity.

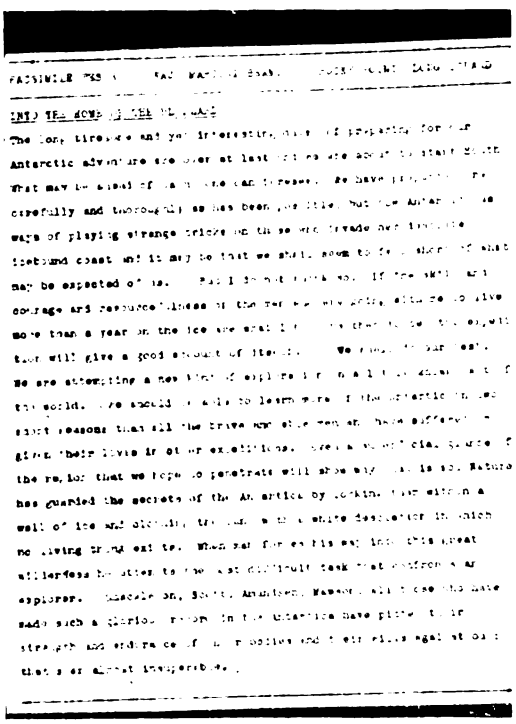

FIG. 10.

Effect of echo on a facsimile sent from New York to Somerton on 22 metres, speed 15 ins. per minute, at 0620 G.M.T., October 22nd, 1928.

It is now the conclusion of Marconi research engineers that an eleven-year cycle will ultimately be found to exist for the best wavelengths for any given distance, corresponding to the eleven-year sunspot cycle.

Specimens of the facsimile records obtained in the 1931 tests and the facts they disclose will now be discussed.

The signal transmitted by facsimile was a thin line drawn on the paper normal to the direction of the scan, and by running the receiver facsimile drum at 57·6 ins. per second, which was four times the speed of the transmitter drum, the line received was made four times the width transmitted, and it was cut up into sections and the prints became striped, as shown in the figures which follow.

It may be mentioned here, that although the picture transmitted consisted of several lines transverse to the direction of scanning, which were drawn one below the other and well spaced apart, the illustrations shown are typical sections of one such line only from each print. Also the wavy character of the line, which appears in some of these illustrations, is not material, as it was produced by slight variations in the speed of the scanning spot from four times the normal, for which due allowance could be made when measuring echo duration.

Facsimile Tests Somerton - Montreal 32 Metres and 16 Metres.

The first of these, Fig. 13, gives a series of results received at Somerton from

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Montreal on 32 metres, commencing at 8.45 p.m. on the 10th May and ending at 4.05 a.m. on the 11th May.

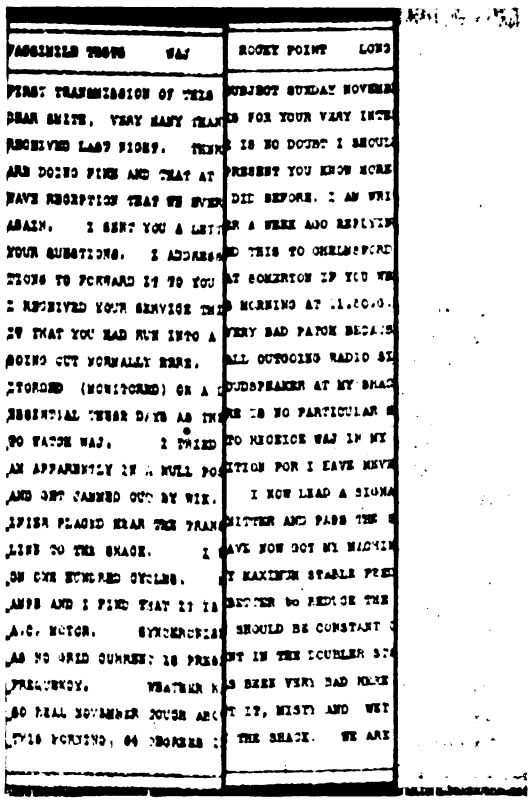

FIG. 11.

Effect of echo on facsimile sent from New York to Somerton on 22 metres and speeds of 15 ins., 10 ins., and 30 ins. respectively at 1415 G.M.T., November 8th, 1928.

It will be noticed that there is one main band of signals, which varies in width according to the hour of the day, and this is the original line signal, which has been broadened to a greater or less extent by the multiple echo effects of rays leaving the transmitter at different vertical angles.

There is also a broken secondary line shown in the first three prints following the main signal band. This is produced by a distinct group of rays leaving the transmitter at a higher angle than the main signal group. More than one explanation can be offered for the absence of rays between the two groups.

It will be noticed that in the evening the echo is strong, as the ionic density is still very high, whereas in the early morning, when the ionic density is at a minimum and more rays escape through the layer, the signals are almost free from echo.

A very interesting comparison is given in Fig. 14 between the normal echo conditions on 32 meters and on 16 metres. In his multiple signals paper, when discussing the results obtained on 22 metres,* Eckersley had claimed that one method of reducing echo was to employ a shorter wavelength, because more high angle rays would pass through the layer and would therefore be lost from the signal than would be the case with a longer wavelength. The actual gain to be expected by decreased total echo duration as a result of employing a wavelength of 16 metres instead of 22 metres, he illustrated by the curve shown in Fig. 15. It was not possible to demonstrate this at the time, but

* T. L. Eckersley, "Multiple Signals in Short Wave Transmission." Proceedings Institute Radio Engineers. Vol. 18, No. 1, January, 1930.

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now the comparison of the 32 metres with the 16 metres, as shown in these prints, has confirmed his assumption.

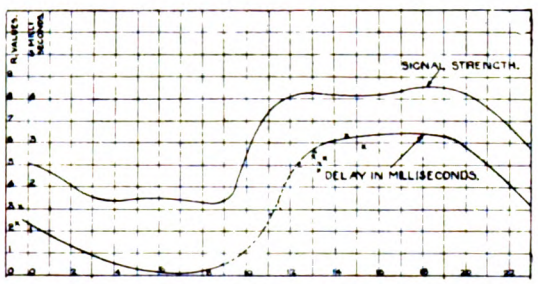

FIG. 12.

Echo duration and Signal strength at Somerton. New York transmitting on 22 metres, October —November, 1928.

Facsimile Tests Somerton —Cape Town 32 Metres and 16 Metres.

Now all the facsimile signals so far discussed have been received in an East and West direction. It was expected that some difference might be observed when working facsimile in a North and South direction, and this has been confirmed, the facsimile records obtained at Somerton from Cape Town on 32 metres and on 16 metres giving less echo, different echo times, and other effects which are still under analysis to determine why they differ from the Canadian results.

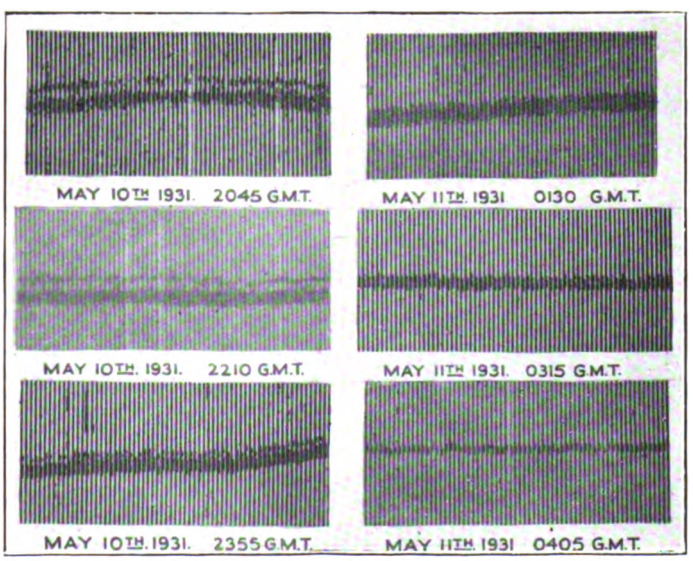

FIG. 13.

Facsimile echoes received at Somerton from Montreal on 32 metres, May 10th-11th, 1931.

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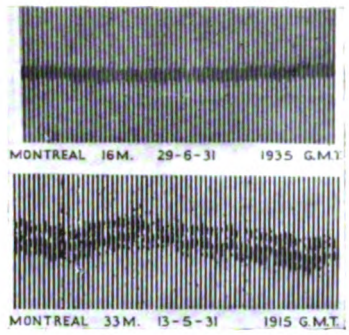

FIG. 14.

Comparison of facsimile echoes received at Somerton from Montreal on 33 metres, at 1915 G.M.T., 13th May, 1931, and on 16 metres, at 1935 G.M.T., 29th June, 1931.

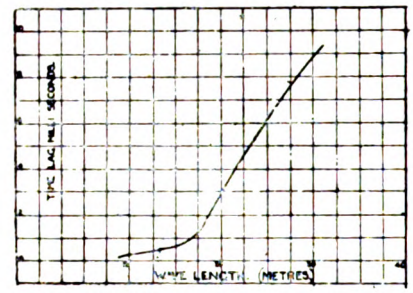

FIG. 15.

Estimated multiple echo duration at different wavelengths.

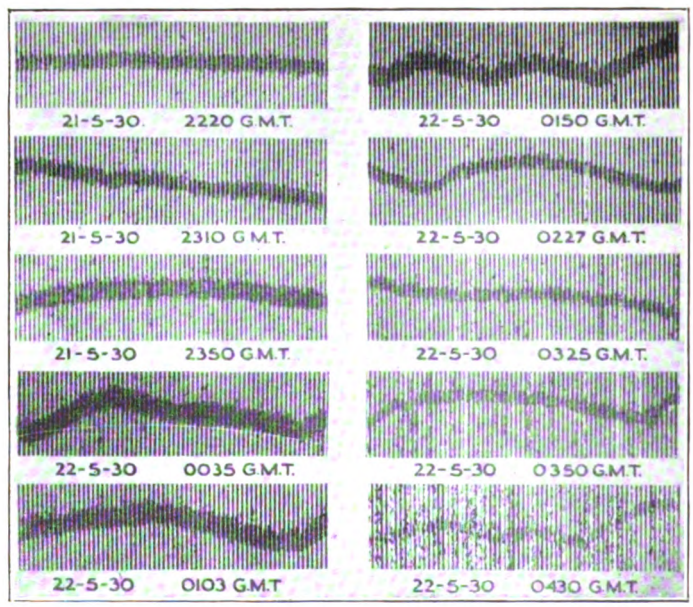

FIG. 16.

Facsimile echoes received at Somerton from Cape Town on 32 metres, from 2220 G.M.T., May 21st, to 0430 G.M.T., May 22nd, 1931.

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It may be mentioned that in addition to being North and South instead of East and West, the signals from Cape Town travel almost twice the distance of those received from Montreal—the great circle distances being 9,500 km. and 5,500 km. respectively—also the Cape signals travel mostly overland, while the Montreal signals travel mainly over sea, so that without more evidence one hesitates to give all the credit for the improved results to the direction of transmission.

A typical example of the normal variation of echo during the night on 32 metres is shown in Fig. 16. It will be seen that towards the early morning the echo disappears, due to the increase in the layer absorption, but so also does the strength of the signal disappear, and at 4.0 a.m., the facsimile may be free from multiple effects, but it may also be too weak to give a good print.

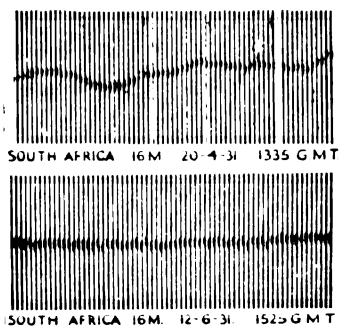

FIG. 17.

Facsimile signals at Somerton from Cape Town on 16 metres at 1525 G.M.T., June 12th, 1931. Good normal conditions. Also on 16 metres, at 1335 G.M.T., April 20th, 1931. Unexplained high angle wipeout at this hour.

(B) At 5.0 a.m., signals had completely faded out. Of course, in practice, the stations have by this time switched over to the day wave of 16 metres, and Fig. 17(A) gives an example of good normal conditions on this wavelength, which is suitable for facsimile and probably for television.

(A) The other facsimile on the slide No. 17(B) illustrates one of the puzzle effects on the South African circuit which up to the date when this paper was written, had yet to be explained. Judging from the height of the sun at the hour when this facsimile was transmitted, that is at 1335 G.M.T., the ionic density should have been a maximum, as this state is reached about 1 hour 40 minutes after the sun passes the zenith of the great circle between the transmitting and receiving stations, and therefore the echo effects should also have been a maximum. Instead of this, signals show very little echo.

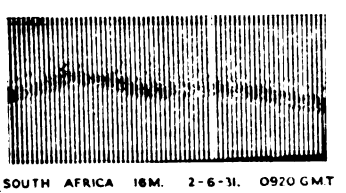

FIG. 18.

Facsimile echoes at Somerton from Cape Town on 16 metres at 0920 G.M.T., June 2nd, 1931, due to scattering.

Fig. 18 illustrates another abnormal case, the type of echo received from scattered signals, that is fairly long period echoes of the order of ·01 sec., which have no definite direction or time relation with the main signal, and the effects of which are in consequence difficult to make provision against.

Then there are peculiar results produced by magnetic storms. One such storm took place on the 14th-15th May, and its effects are illustrated in Fig. 19. At twenty-five minutes before midnight on the 14th May the magnetic

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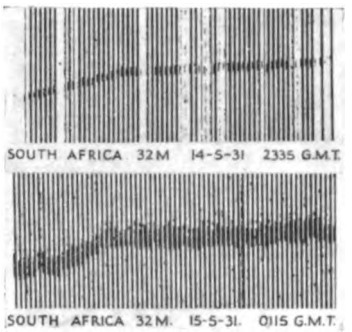
disturbance caused all the high angle rays to be absorbed, which weakened signals and removed echo as shown in Fig. 19 (A), only glancing angle rays coming down to earth again. Five minutes earlier there had been a temporary fade-out. One hour and thirty-five minutes later, that is at 0115 G.M.T., on the 15th May, the same magnetic storm caused the very strong echo and scattering effects shown in Fig. 19 (B).

Fig. 20, shows a result obtained during the same magnetic storm on the 15th May, but on the Somerton-Montreal circuit on 33 metres. It shows the same effect occurring on this route as on the Cape Town circuit, the magnetic storm causing the high angle rays to be absorbed, and in consequence reducing the echo effects.



(A)

(B)

FIG. 19.

Facsimile echoes at Somerton from Cape Town on 32 metres, at 2335 G.M.T., May 14th, 1931, and 0115 G.M.T., May 15th, 1931. Magnetic storm effects.

Conclusions.

Now what conclusions can be drawn from these facsimile tests?

First, that multiple echo effects over long distance are met with on all short wavelengths, but there is much less echo on 15 metres than on 30 metres, and there should be still less echo on a shorter wavelength than 15 metres.

During the twenty-four hours there is usually some period when the echo is not troublesome.

If this is due to the absorption of the medium being greater at this time than at other times, the resulting signal may be too weak for good facsimile or television, but if it is due to the higher angle rays getting through the layer, leaving only the glancing angle rays to come down to earth again without experiencing too much absorption, then the echo-free signal may be strong enough for facsimile or television purposes.

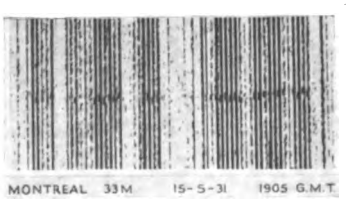


FIG. 20.

Facsimile signals at Somerton from Montreal on 33 metres, at 1905 G.M.T., May 15th, 1931, showing magnetic storm high angle absorption effect.

Clearly if it is possible to employ the direct ray only, this is the best condition for echo-free facsimile and television.

Wavelengths of 1,000 metres to 3,000 metres, which lose all their high angle rays by absorption, could be employed provided the frequency band required by the facsimile or television transmitter were not too wide, and the necessary width of channel were available.

Aerial design should proceed on those lines which concentrate the radiation in a narrow beam at a vertical angle which tests, such as those described by Eckersley, indicate as most suitable for the best results to be

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obtained at the distance required. The narrower the beam in the vertical plane, the less echo may be expected, although no transmitting aerial design has yet been devised which is capable of concentrating the radiation in one sheaf of rays only.

Although it may be expected that the echo times at a great distance are longer than at a shorter distance, owing to the increased difference in the lengths of the paths traversed by the different rays, and also that at a great distance there may be less echo due to more echo rays being absorbed than when they pass over the shorter distance, further observation on these points is necessary to establish what actually happens.

Should it prove to be true that there is an eleven year cycle depending on solar activity, then for the next three years one may expect :—

(A) Less day absorption, as the bottom of the layer will not be so low down.

(B) Less echo on all wavelengths as more high angle rays will penetrate the layer.

(C) In consequence weaker signals on any given wavelength.

(D) To obtain the same field strength at a given distance, the wavelength will have to be increased.

While these changes are in progress, it is hoped that it will be possible to make further tests on a Transatlantic or other long distance radio facsimile circuit, which should enable valuable information to be obtained in support of, or amendment of the theories of the Heaviside layer which have been briefly dealt with in this paper.

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MARCONI PORTABLE FIELD STRENGTH MEASURING EQUIPMENT

It has been apparent for a considerable time that a need exists for a portable field strength measuring equipment and the set described in this article has been designed to meet this need.

It is believed that no other similar equipment exists which is capable of such a high ratio of maximum to minimum field intensity measurement over such a wide range of wavelengths—namely 14 *to* 2,000 *metres.*

THE Marconi Type 205 Field Strength Measuring Equipment which has been available for some two or three years, while being quite satisfactory for use at a fixed point, is unsuitable for use where rapid field intensity measurements have to be made at a number of points such for example, as are required for the determination of polar diagrams or coverage of broadcasting stations and the checking of fundamental to harmonic field strength ratios, etc.

The new portable equipment has been designed to cover a waverange of 14 to 2,000 metres. This range, it will be observed, covers both the upper and lower broadcast bands and permits in addition the measurement of harmonics down to the limit of 14 metres.

A necessity arising from the use of a measuring set for the purpose outlined above is the measurement of much higher field intensities than those of which the Type 205 is capable without detracting in any way from the ability to measure field strengths of two or three micro-volts per metre. That the Portable Field Strength Measuring Equipment meets these requirements quite successfully is shown in this article. See Figs. 1 and 2.

Physical Dimensions.

The physical dimensions of the equipment are as under :—

Height (excluding frame aerial) 2 ft. 4 ins.

Height (including frame aerial) 5 ft. 9½ ins. + 3 ins. with short wave frame.

Width (overall, but excluding ledges) 1 ft. 8 ins.

Width (including ledges) 2 ft. 10½ ins.

Depth (front to back overall) 1 ft. 1 in.

Approximate weight 180 lbs.

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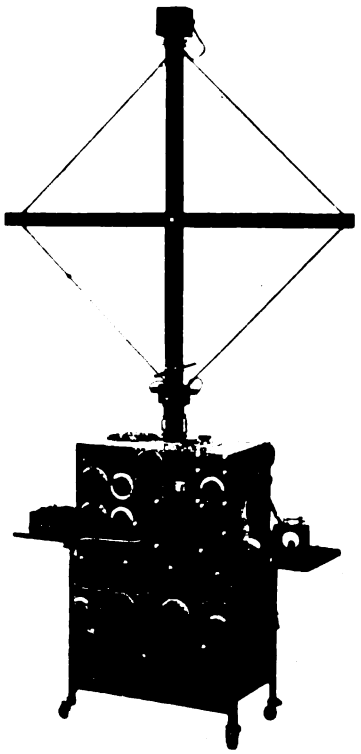
Fig. 3 gives a schematic diagram of the layout of the equipment the units being numbered 1 to 14 are here tabulated.



Marconi Portable Field Strength Measuring Equipment.

No. 1 = Radio Frequency Generator.
No. 2 = Radio Frequency Attenuator.
No. 3 = Radio Frequency Potentiometer.
No. 4 = Mutual Coupling.
No. 5 = Frame Aerial Socket.
No. 6 = Aerial Tuning Capacities.
No. 7 = Receiver Coupling.
No. 8 = R.F. Generator High Tension Battery.
No. 9 = High Frequency Amplifier.
No. 10 = 1st Detector and Change Frequency Oscillator.
No. 11 = 1st Stage Intermediate Frequency Amplifier.
No. 12 = 2nd Stage Intermediate Frequency Amplifier and 2nd Detector.
No. 13 = Receiver High Tension Battery.
No. 14 = Two Adjustable Ledges.

NOTE.—The low tension batteries are located inside the R.F. Generator and Receiver compartments respectively.

Radio Frequency Generator.

A Hartley type circuit is used for this unit, the output being controlled by fixed coupling coils contained within the interchangeable range blocks and these in turn are shunted by a 200 ohm variable potentiometer. This arrangement requires very little space in which to operate and eliminates the separate substitution of different coupling coils with a change of waverange and provides a fairly smooth output current variation. An easily accessible thermo-junction in series with the output is contained within the R.F. generator compartment and the output current is read on a " plug in " Cambridge type " L " galvanometer. Two thermo-junctions are supplied with the equipment with ranges of 0—25 milliamperes and 0—50 milliamperes respectively. The 0—25 milliamperes junction is for general use and the 0—50 milliamperes for use when it is desired to measure field intensities at or approaching the maximum of which the equipment is capable, it being noted that

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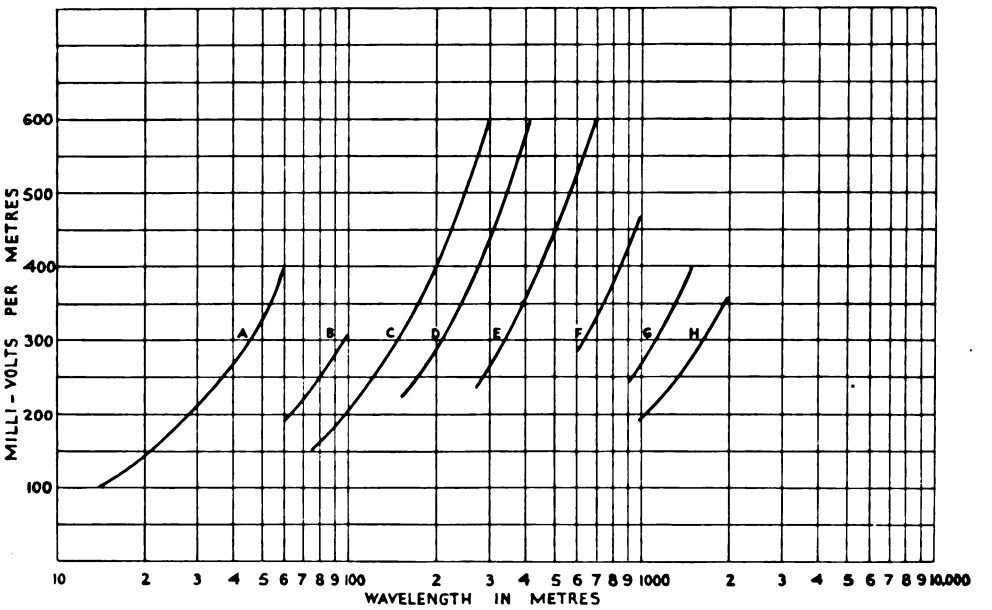

FIG. 1.

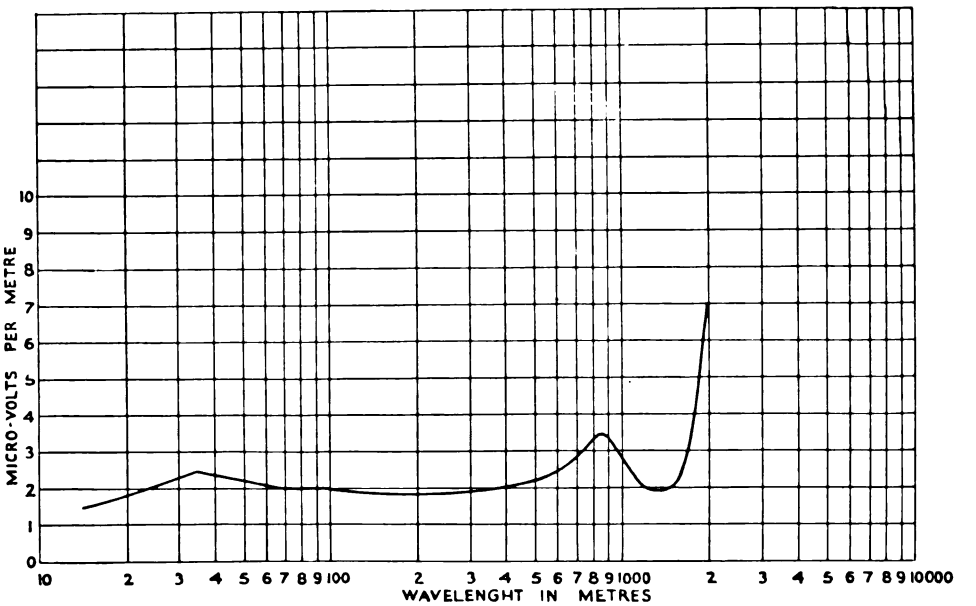

FIG. 2.

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the output of the attenuator varies directly as its input current. The valve used in the R.F. generator is Type P.215.

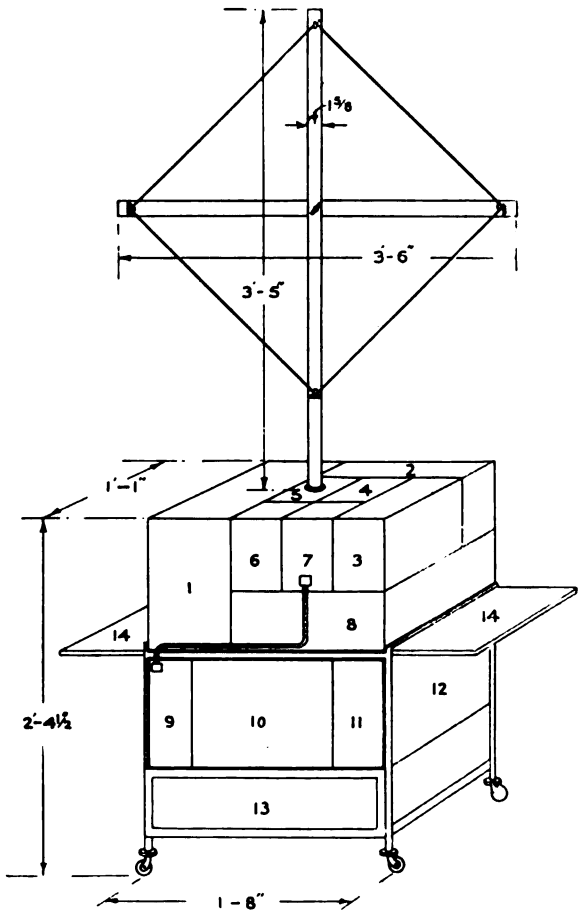

FIG. 3.

The Radio Frequency Attenuator.

This unit is based upon the Type 205 attenuator which is fully described and explained in "Short Wave Signal Measuring Apparatus," I. and II., by T. L. Eckersley, in THE MARCONI REVIEW of May and September, 1929, respectively. Although theoretically identical with that used in Type 205 this unit has been completely re-designed mechanically, resulting in a very large saving of space and weight, greater accessibility and more straightforward operation. The whole series

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portion of the " T " network is in two units (instead of five), both of which can easily be withdrawn after releasing connections should the necessity arise.

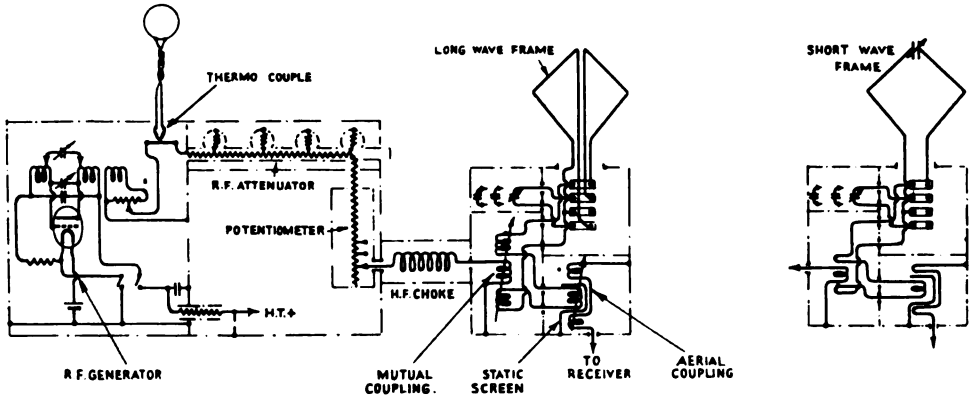

FIG. 4.

The shunt resistances also easily accessible, are operated by a cam shaft through a control handle, which is clearly marked for each position, at the end of the unit. The output potentiometer and choke coils remain as those in Type 205.

Mutual Couplings.

The physical dimensions of these have been kept very small and designed to be quickly interchangeable. Three different values of these are supplied.

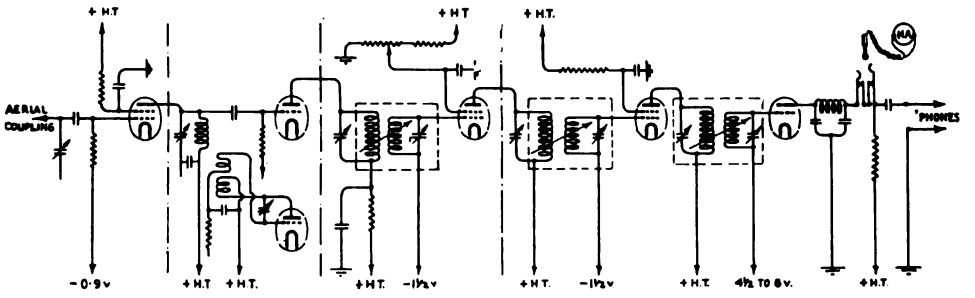

FIG. 5.

Aerial Frame Loops and Tuning Capacities.

The frame is more or less of skeleton construction, light in weight and designed to fold into a minimum of space for transportation. The flexible interchangeable loops are readily attached to the frame and easily folded into small space when not

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in use. Six aerial loops are required to cover the range 14—2,000 metres. The aerial tuning capacities, with suitable control switch, are contained in the body of the R.F. generator and attenuator unit. For wavelengths below 75 metres the tuning capacity is attached to the top of the frame.

Superheterodyne Receiver.

In this unit one stage of high frequency amplification, the grid and anode circuits of which are gang tuned, precedes the first detector. The high frequency valve (S.22) anode winding and the change frequency oscillator windings are carried on a single former so that both are changed in one operation. The change frequency oscillator circuit is similar to that of the R.F. generator and uses a P.215 Type valve. Both detector valves are Type H.L.2 and the intermediate frequency valves are Type S.21. Two volt valves being chosen from considerations of weight and space required by L.T. batteries. The intermediate frequency amplifier operates on a frequency of 110 kilocycles with band pass intervalve couplings. No low frequency circuits are included in the circuit as the receiver is sufficiently sensitive to give the required deflection on a 0—500 microammeter in series with the 2nd detector anode on very weak signals. Output is controlled by screen grid voltage variation on the first I.F. valve.

Operating Features.

An outstanding advantage of the superheterodyne receiver as used in this equipment is the greater speed of operation as compared with the Type 205 equipment. The check of the equality of frequency between the incoming signal and the R.F. generator is quickly and easily accomplished, by tuning the latter to zero beat with the former. Alternatively, if the receiver is accurately tuned to the incoming signal and the signal be then removed (by swinging the frame to zero position) the R.F. generator is easily and accurately tuned to the correct frequency against the deflection of the receiver output meter. Far more accurate measurement of I.C.W. or tonic train signals is also possible with this equipment. The operator has no need to move from his seat throughout the process of taking a field strength measurement.

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MARCONI SHORT WAVE RECEIVER

TYPE Rg.31a

Until comparatively recently short wave radio channels have fallen naturally into two broad groups.

(A) *First class commercial circuits, comprising duplex high speed telegraph and duplex telephone services.*

(B) *Simple installations for simplex working (e.g., ship telegraph channels, field stations, aeroplane equipments, etc.), nearly all of which employ a simple receiver, embodying usually one high frequency stage, a self-oscillating detector, and one or more L.F. stages.*

There is now a rapidly growing demand for services falling between the two types mentioned above.

Such a case is that of a liner fitted for ship-shore telephony. The short wave telegraph receiver in such circumstances has to carry on reception through the short wave telephony transmissions, and with exacting conditions of space and frequency separation.

The simple type of receiver hitherto satisfactory is now inadequate for the purpose, and it is precisely for this type of demand that the type Rg.31a duplex short wave receiver described below has been developed.

It is primarily intended for headphone reception, but embodies provisions for the addition of another unit for recording on secondary commercial circuits. In this form it is known as the Rg.32a.

General Description.

THE Type Rg.31a receiver is of the double detection type, and covers a waveband of 15/200 metres, by means of five sets of plug-in coils. It is suitable for use with a simple harmonic aerial, or balanced feeders. It can also be supplied to take concentric tube feeders and may therefore be used on land installations with a simple aerial array.

It is designed for bench mounting and is provided with lugs for bolting down on to shock absorbers.

The upper half of the receiver (see photograph) contains five separately screened compartments housing the signal frequency circuits.

The lower half contains the separately screened compartments of the intermediate frequency amplifier, the second detector and second heterodyne, and a stage of low frequency amplification.

Taking the signal frequency circuits first, they comprise :—

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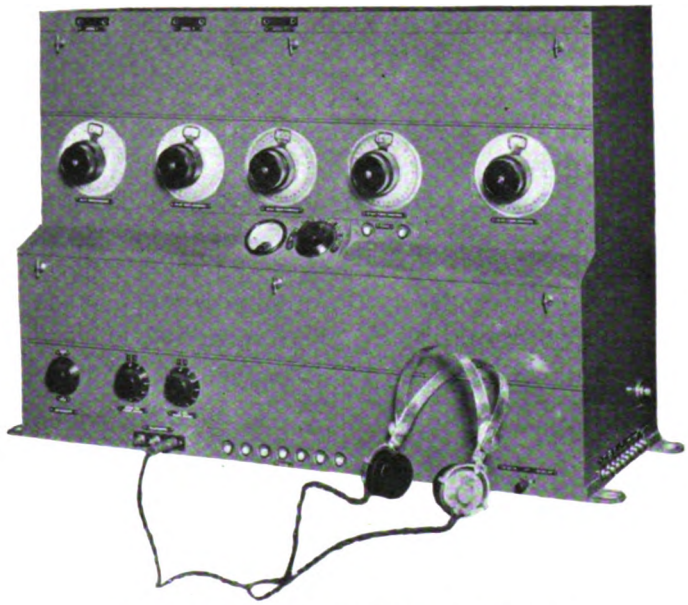
(1) The feeder terminating tuned circuit. A variable magnetic coupling via an electrostatic shield is provided between this circuit and

(2) An intermediate tuned circuit coupled by means of a small variable condenser to



Marconi Short Wave Receiver, Rg.31a.

(3) The tuned grid circuit of a signal frequency amplifying stage.

(4) The first detector and the tuned transformer coupling it to No. 3 above.

(5) The first heterodyne. This is mounted as a unit sprung as a whole with reference to the main container to lessen vibration troubles.

The first heterodyne changes the frequency of the received signal to 100 kcs., i.e., the mid-frequency of the intermediate frequency filter amplifier.

This consists of four circuits coupling the first detector output to the second detector input via three stages of screen-grid amplification.

The required form of intermediate frequency response curve is obtained by combining three single tuned circuits and one double tuned circuit, and it may be stressed that these intermediate frequency tuned circuits incorporate lumped

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resistances of such a value as completely to mask variations in the resistance of the coils themselves. Variations in the intermediate frequency amplifier performance due to climatic and other conditions are thereby minimised.

The second detector valve holder is duplicated and the second heterodyne inducing into the grid circuit may be used :—

(1) In the standard Rg.31a, to beat the signal to the desired audio-frequency, after which it passes to the telephones via the transformer-coupled L.F. stage, or

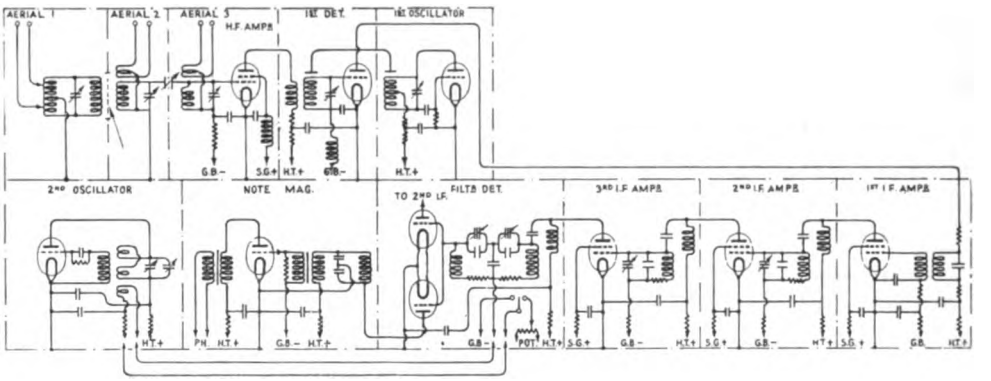

FIG. 1.

(2) To beat the signal to a second intermediate frequency at which it is again amplified and rectified by a second unit. This corresponds to the type Rg.32a outfit, and the auxiliary second detector valve is then inserted and used to feed the second unit, the normal telephone output being available as a monitoring point. Reference to the circuit diagram, Fig. 1, will make this clear.

Thorough de-coupling is provided in all supply leads entering the separately screened compartments.

The components in each compartment are assembled in unit form on a small base held in position by a single knurled knob. Full inspection of any component can therefore be obtained by removing either the top or bottom half of the front panel and withdrawing the unit, after freeing the feeding connectings.

Full metering facilities are provided in a simple form by the meter seen mounted on the receiver. This may be switched to read :—

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(A) Individual valve feeds as selected by push-buttons.

(B) L.T. volts.

(C) H.T. volts.

(D) Feeds and supplies to the additional optional recording unit when fitted.

Selectivity.

In a double-detection receiver the attenuation of unwanted signals must be specified for cases where :—

(A) The interfering signal lies on the same side of the first heterodyne as the desired signal.

(B) " Image signal " interference occurs, i.e., a signal lying on the opposite side of the first heterodyne to the wanted signal beats with the former to the intermediate frequency.

(C) Two unwanted signals enter the first detector and beat together to the intermediate frequency, i.e., second channel interference.

To type (A) interference, the selectivity of the receiver is practically that of the intermediate frequency filter amplifier. It is a fact that cannot be fully discussed here that with this type of filter-amplifier it is easier to obtain the required gain and band-width the *lower* the intermediate frequency.

Interference of types (B) and (C) can be attenuated only at the signal frequency, and for a given signal frequency response curve the attenuation will be higher the *higher* the intermediate frequency.

The compromise intermediate frequency usually adopted to meet these two conflicting requirements is of the order of 150-200 kcs., but in the type Rg.31a receiver the value chosen has been 100 kcs. This has been deemed essential in order to keep the intermediate frequency below the lowest transmission frequency used in ship work, bearing in mind that the receiver will in many cases be housed in the same cabin as a ship's long-wave transmitter.

The intermediate frequency response curve has a bandwidth of 6 kcs. at 6 db. down from maximum gain, and at 40 db. down from maximum gain is only 20 kcs. wide.

Such a response curve is capable of passing adequately all commercial speech frequencies in cases where telephony reception is required, but still gives ample attenuation of signals only 10 kcs. away from the desired signal.

With reference to " Image Signal," attenuation, measurements show that at 5,200 kcs. (57.69 metres) this is approximately 60 db. ; at 1,700 kcs. (17.65 metres) the attenuation is approximately 20 db.

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Sensitivity.

The detailing of the receiver gain at various frequencies is of little real help in relating field strength and output, but the distribution of the overall gain may be of interest, and is as follows :—

Signal frequency—varying from 5 db. at the highest frequency to 20 db. at the lowest.

Intermediate frequency—85 db.

Audio-frequency—20 db.

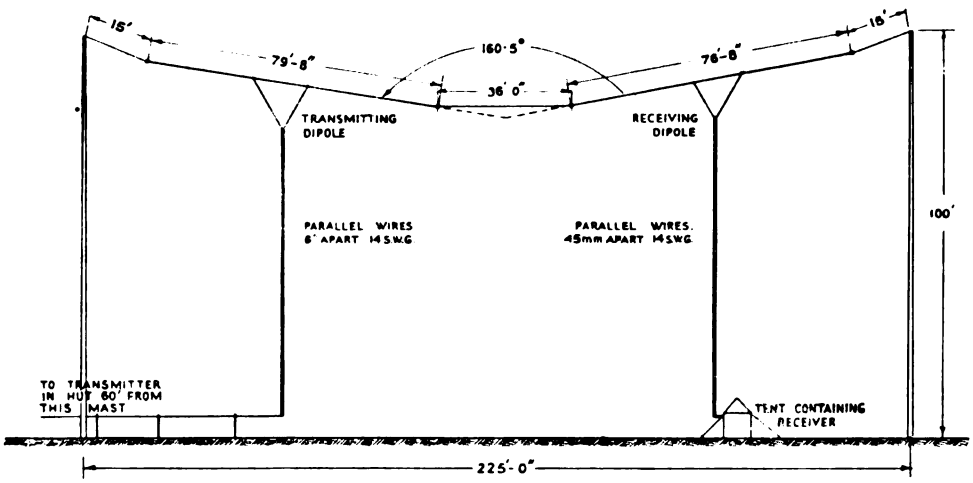

FIG. 2.

For more informative definition of the overall sensitivity of the receiver it is necessary to relate the signal field strength (inducing in a correctly terminated half-wave aerial) and output.

Assuming that sensitivity to telephony reception is in question, it is usual practice to give the relation between carrier field strength and micro-amps push-up in the second detector. For a given modulation percentage the audio output to a 600 ohm line can be then easily determined.

Measurements made in connection with this point show that if the second detector is biased to an idle current of 200 micro-amps a push-up of 100 micro-amps is obtained with carrier field strengths between 2 and 20 micro volts/metre, according to the received frequency.

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When however considering C.W. telegraph signals as read in the head-phones, the final and only practical criterion of sensitivity must relate field strength (with the assumed aerial) and the signal heard in the phones at full voice-frequency gain.

Measurement has determined that comfortable C.W. signal strength (R7) is obtained with field strengths considerably below one micro-volt/metre.

Manipulation.

The receiver is simple in operation. When searching for a station the aerial or feeder, as previously stated, may be plugged into the radio frequency amplifying stage, in which case the tuning controls consist of the tuning condensers of the radio frequency amplifier, the first detector and the first heterodyne.

Having found the required station the aerial may be plugged-into the second tuned circuit and then to the first tuned circuit.

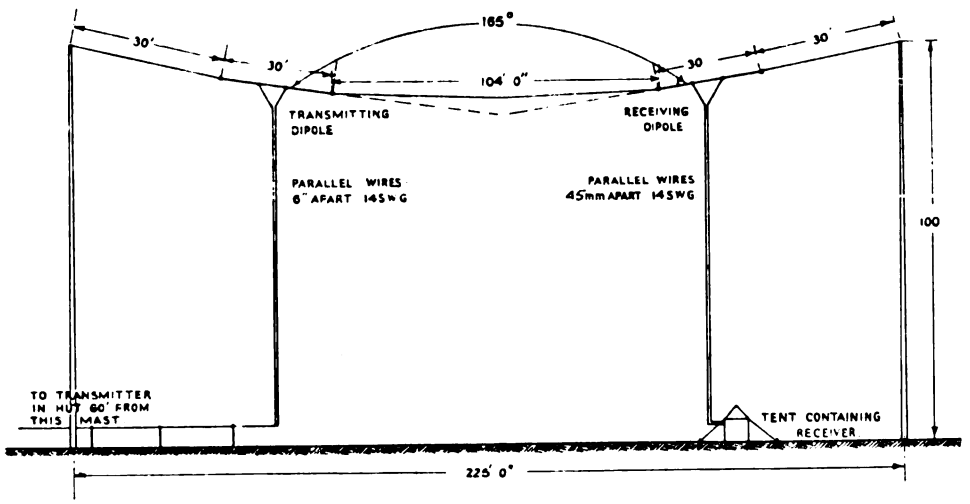

FIG. 3.

The remaining controls of the radio-frequency circuits consist of the continuously adjustable feeder termination and the variable mutual between the first and second tuned circuits.

Apart from the radio frequency controls, separate volume controls are supplied for both the intermediate frequency and the low frequency gain. There is also, of course, a condenser tuning control for the second heterodyne and this covers a frequency range of from 80 to 120 kcs.

For aural beat reception the second heterodyne is set to either 99 or 101 kcs., i.e., to give a 1,000 cycle note with the mid-frequency of the intermediate frequency amplifier.

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When, however, the second recording unit is supplied, the second heterodyne must be adjusted to either 85 or 115 kcs. This will beat the signal to 15 kcs. which is the mid-frequency of the second intermediate amplifier embodied in the recording unit.

A switch is provided to switch off the second oscillator when it is desired to receive telephony or I.C.W.

Duplex Working.

By confining by far the major portion of the gain to the intermediate frequency filter amplifier, it has been possible to introduce three tuned circuits between the aerial and the first valve. By thus minimising shock excitation effects it is possible to carry out duplex reception with very small percentage separations from a nearby transmitter.

Tests have been carried out to determine the performance of the receiver in this regard and Figs. 2 and 3 show the aerial arrangements which were used for these tests.

The power in the transmitting aerial was 2 kw. and it was possible to read an R6 signal having a frequency separation from the transmitter frequency of rather less than one per cent.

This test was made at frequencies of 5,200 kcs. and 17,000 kcs.

For the former frequency the aerial arrangement of Fig. 2 was used and for the latter that of Fig. 3.

The above results would only be possible, of course, with a transmitter employing a method of keying which did not produce heavy key clicks, and with the usual precautions to minimise noise from machines and stray currents in stays, etc.

In addition to these tests the receiver has been installed on the "Empress of Britain" and proved capable of carrying on the ship's short wave telegraph reception with complete immunity from interference by the ship's short wave telephone transmitter. Frequency separations of the order of 2 per cent. are involved.

Valves and Supplies.

The standard type Rg.31a receiver employs 4 volt valves of the 0.1 amp type, the L.T. consumption being approximately 1.0 amp.

The H.T. consumption is approximately 25 milliamps at 130 volts.

Grid negative is obtained from a potentiometer across which must be connected a 10 volt battery. The potentiometer takes 25 milliamps, so that a H.T. supply of 140 volts with an earth tap at +10 may be used and will be uniformly discharged.

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POLISH NATIONAL BROADCASTING

Information received from Poland indicates that the broadcast transmitter, installed by Marconi's Wireless Telegraph Company, at Warsaw, provides an efficient service over the whole of Poland.

The field strength distribution of this station and the broadcast facilities of Poland are briefly discussed in the following article.

THE problem of providing a National Broadcast service is exercising the minds of many Radio Technicians at the present moment.

The difficulties to be overcome are different for each country. Physical characteristics, density of population, Language and Finance, are among the problems encountered.

In dealing with any new project it is of value to know how others have dealt with a similar problem and particularly the results obtained.

We are thus indebted to the Polskie Radio for one of the most complete signal strength distribution surveys ever made.

This Survey was undertaken under the direction of the Technical Director of the Polskie Radio, Mr. Wladislaw Heller, and carried out by Engineer, Mr. Tadeush Znanieki.

All measurements were made in full daylight and in over 350 different places.

The results obtained were finally checked in a simple and practical way by sending to all Postmasters a Questionnaire in which they were requested to record to what extent crystal reception of the Warsaw Programmes was possible in their particular districts.

An analysis of the returned questionnaires showed that Warsaw was receivable all over Poland with Crystal Receivers there being remarkably few exceptions.

An important fact has thus been established, that it is possible to provide a truly National Broadcast service in a large country like Poland by means of a single Broadcast Station.

None the less it must be recognised that this excellent distribution is in part due to the wavelength employed, i.e., 1,411 metres, the height of the aerial supporting structures; 200 metres, the Power used; 120 kw. carrier wave energy with linear 80 per cent. modulation, and perhaps not least an almost perfect site, all contributing to the result. This site is 22 km. from the city of Warsaw, and the Station is built on fine hard sand with water flowing underneath at a depth of about 1 metre.

In Fig. 1 we reproduce the Field Strength Signal Chart as obtained by the Polskie Radio.

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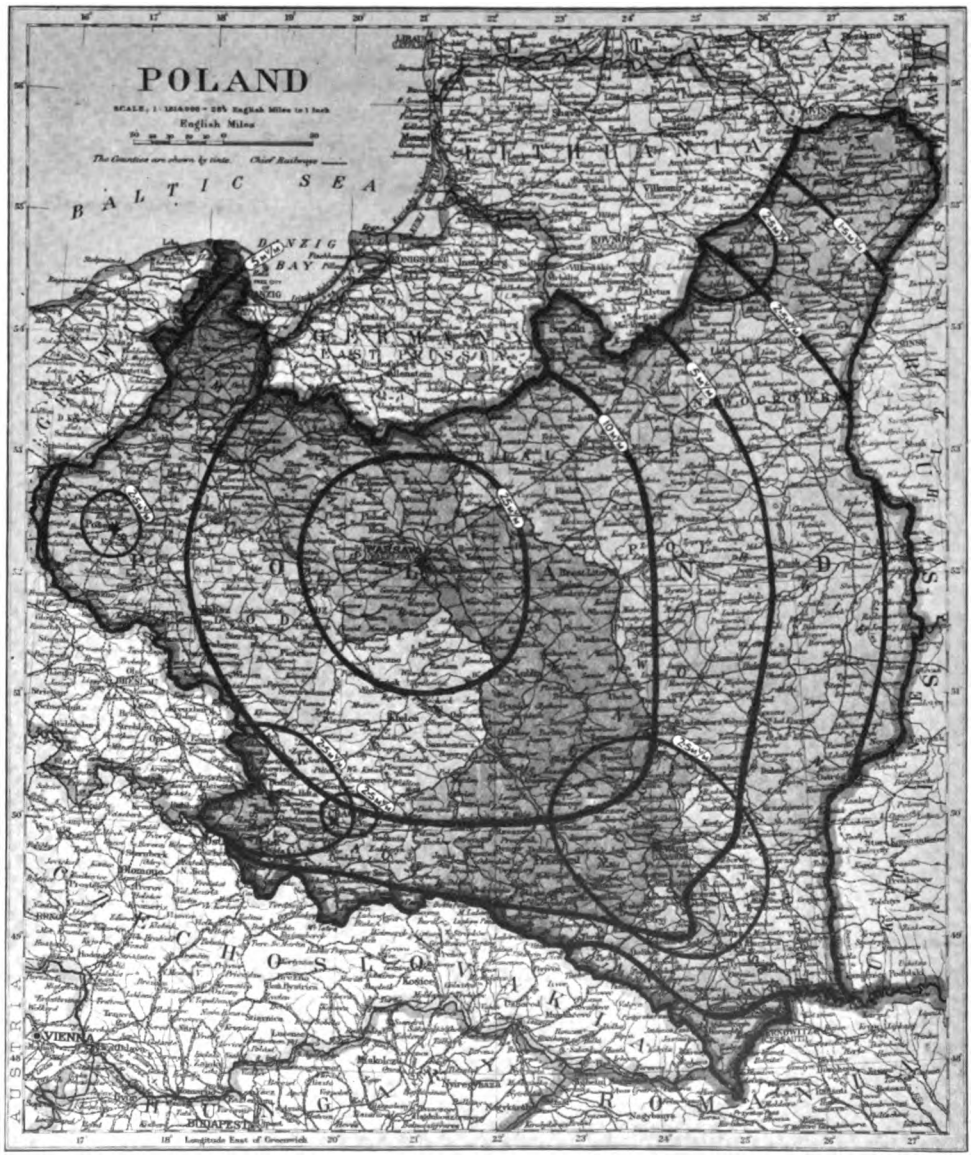

Map of Poland indicating field strength distribution of Warsaw broadcast transmission.

The original chart has been reproduced on another map showing the principal towns and places named in accordance with common usage in order that the various towns may be easily recognisable by Continental and English readers.

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The chart shows a remarkably uniform field strength distribution within the 10 milli volt per metre boundaries, although on the 5 and 2.2 m.v. boundaries the effect of the Carpathian Mountains is clearly shown.

The Regional stations in the vicinity of the towns of Lwow (Lemberg), Vilna and Katowice, show vastly different field strength distribution curves although the powers of the Local Transmitters are of the same order. Lwow and Vilno are each of 16 kw. and Katowice of 10 kw. carrier wave energy, all of which transmit on the Medium Band of Broadcast wavelengths.

It may be of interest to record that Lemberg and Katowice are often heard in England at about the same strength as the Warsaw High Power Station but only on occasion thus showing the unreliability of the medium wavelength transmission for wide area national services.

Fading, the bugbear of Radio Broadcast, is ever present in some degree, but as is well known becomes of less and less importance as the length of the transmitting wave is increased. For Warsaw the fading radius is about 230 kilometres. The fading radius increasing during the summer months to an amount which extends beyond the frontiers of Poland.

This has an important advantage, in so much that it is now a normal practice for the Regional Stations to retransmit the Warsaw programme by the means of direct Radio Relay. In fact 95 per cent. of all Polish simultaneous transmissions are carried out by Wireless, even although an excellent system of telephone lines exist connecting Warsaw with Lwow, Vilna, Katowice, Pasman and Lodz.

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MARCONI NEWS AND NOTES

KELVIN MEDAL AWARDED TO MARCHESE MARCONI

Electrical Review

Lord Rutherford presenting the Kelvin Medal to H.E. Marchese Marconi.

THE Kelvin Medal Award Committee, after consideration of representations received from the leading engineering societies and organisations in all parts of the world, have awarded the Kelvin Medal for 1932 to His Excellency Marchese Marconi.

The presentation was made by Lord Rutherford in the Great Hall of the Institution of Civil Engineers, London, on May 3rd. Sir Cyril Kirkpatrick, President of the Institution, presiding at this function, said that in his view the honour was the highest which could be bestowed on a member of the engineering profession.

In presenting the medal, Lord Rutherford said that in an age of great scientific advance no development had excited more interest than the practical application of electrical waves for signalling through the ether to all parts of the earth. Marchese Marconi was a pioneer in this conquest of nature who had done more than any other man to make possible this system of rapid world-wide inter-communication.

Traffic Control by Wireless.

MARCONI apparatus, which has solved many varied problems of communication, was called upon to assist the London police in the control of traffic on the crowded roads leading to the Epsom Downs on Derby Day (June 1st).

An Autogiro, a type of aircraft which can be made to hover almost stationary over any particular spot, was fitted with a Marconi short wave portable telephone transmitter and a Marconi aircraft receiver. Traffic control experts flew in this machine above the roads leading to Epsom and telephoned instructions to their colleagues on the ground who were able to obviate traffic jams which threatened at cross roads and other possible danger spots. The unimpeded flow of traffic was thus greatly facilitated.

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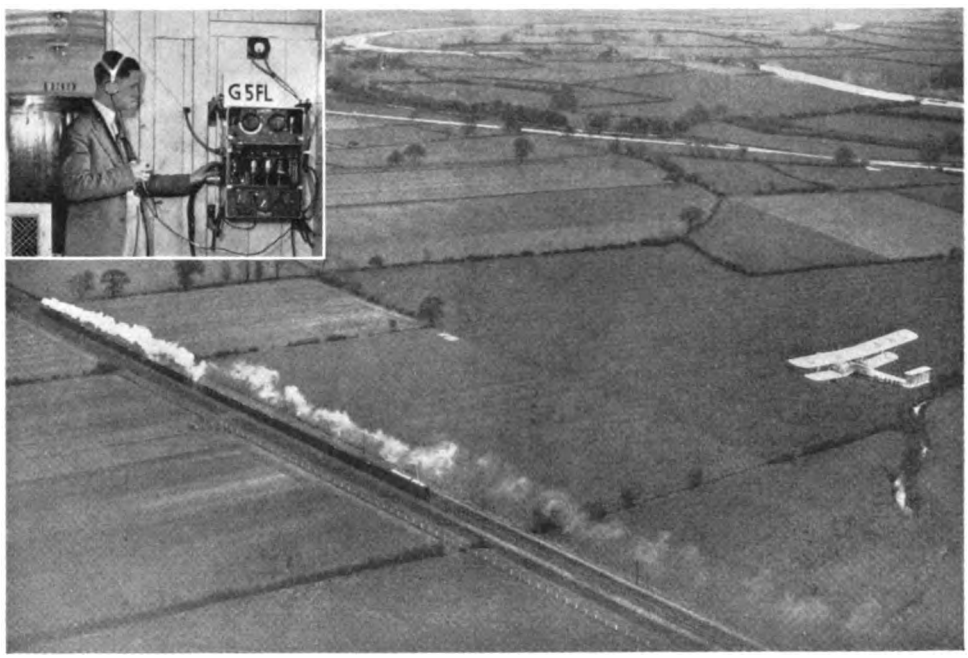
The ground station consisted of a motor van fitted with a Marconi short wave aircraft receiver, Type A.D.27a, and a Marconi short wave telephone transmitter, and excellent two-way communication was maintained with the Autogiro throughout the busiest hours on the roads.

Train-Aeroplane Wireless Telephone.

THE enormous advance made during recent years in wireless communication for moving vehicles was graphically demonstrated by an experiment carried out on May 20th by the Marconi Company in co-operation with Imperial Airways Limited and the London & North Eastern Railway Company.



Imperial Airways liner "Heracles" flying above the "Flying Scotsman" during the wireless telephone tests.

A Marconi aircraft transmitting and receiving equipment was installed in a rail van 60 feet in length, which was attached to the "Flying Scotsman," one of Britain's fastest express trains, leaving London at 10 a.m. for Edinburgh, Scotland. The 42-seater Imperial Airways liner "Heracles," which carries Marconi wireless apparatus as part of its standard equipment, left the London Air Port, Croydon, at 11 a.m. on Friday for Glasgow, Scotland.

The aeroplane overtook the train near Grantham, just over 100 miles north of London, and while the train and aeroplane were travelling at speed, wireless

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Prince George (right) at the Marconi Works, with H.E. Marchese Marconi.

telephone communication was established between them and a number of conversations were exchanged. Communication was maintained continuously for more than half an hour and all who took part in the experiment, including representatives of the principal British newspapers, commented upon the clarity and distinctness of the speech both in the train and in the air.

Prince's Visit to Marconi Works.

PRINCE GEORGE, youngest son of H.M. King George V., visited Chelmsford on May 25th, and during a busy day in the town inspected the Marconi Works.

At the entrance to the Works, Prince George was received by His Excellency Marchese Marconi, President of the Company, Lord Inverforth, Chairman of the Board, and Mr. H. A. White, General Manager.

The Prince made an extensive tour of the Workshops and was shown various types of wireless stations which were being manufactured for export to several countries of the Far East, South America, and Continental Europe. He expressed great interest in the construction and workmanship of Marconi broadcasting transmitters and special classes of Marconi equipment such as Direction Finders.

Mr. St. John Philby.

THE congratulations of the Marconi Company are extended to Mr. St. John Philby on his accomplishment (January-April, 1932) of one of the most remarkable Arabian desert journeys on record.

Mr. St. John Philby, who is an adviser to King Ibn Saud and an outstanding authority on Arabia, was mainly responsible for the introduction of wireless telephone and telegraph communication between the principal cities of the Hedjaz and Nejd. For these services eleven Marconi fixed stations and four Marconi mobile stations, fitted in lorries, are being installed.

Mr. Philby's recent journey of exploration, in the course of which he crossed 350 miles of waterless country, extended from Hasa, on the Persian Gulf, to Mecca.

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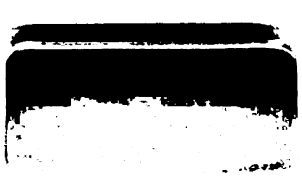

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